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QUALITY ASSURANCE

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COVER: Editors' Concept of Quality Assurance

Quality Assurance Program For Western Union

On Christmas, 1968, three American astronauts were in orbit around the moon. To support their existence within the frail craft, so that they could successfully complete the mission, were hundreds of systems—thousands, if you count the ground support systems. Each of these systems, some of them brand new, had to function perfectly. As we all know, their flight was a success and now stands as the high point of America's space exploration. Also, we are aware that this flawless performance has been credited not only to the ingenuity of the designers, but to the unflagging application of a comprehensive Quality Assurance program. The value of Quality Assurance has now been dramatically illustrated, however, it has application to our programs, and is an essential ingredient in providing customer satisfaction.

Western Union has been making use of Quality Assurance techniques for many years as part of normal work functions and on government projects. In recent months a management team working with John Hart and me has been studying

R. H. McConnell
Asst. Vice President
P. & E.O.

our operations to consolidate, document and expand these efforts. The team has proposed that additional emphasis be placed on Quality Assurance, that everyone, particularly the engineers, be aware of and able to use the techniques that help assure quality and reliability. This proposal has been well received and the team was asked to implement their recommendation.

The team first established the definitions applicable to Western Union's environment. They then studied how the existing work functions produced quality. Selecting the best available work systems of guidelines, requirements and procedures, modifying some working systems so that they would better serve, and adapting systems developed and proven in other organizations, the team put together a program they felt would place this added emphasis on Quality Assurance. That this program could be implemented, the team, with assistance from many others, wrote and published the Quality Assurance Manual.

This issue of the TECHNICAL REVIEW takes a look at the management systems which the team detailed to place an added emphasis upon those techniques which made it possible for man to orbit the moon and which we expect to help Western Union to provide customer satisfaction. I would like to point out that to my knowledge this is the first time a formal Quality Assurance Program has been designed for use within a communications public utility. I believe that the following articles are significant and hope that they are of interest to the readers.

R H McConnell

Quality Assurance Emphasized

by John Hart III

It has always been Western Union's objective to satisfy its Customers. Because of the complexity of our new systems and new services, Quality Assurance, as applied to every aspect of the design, implementation, installation, and maintenance of these services, is more important than ever before.

Western Union was established in 1851 to provide telegraph service across a large portion of the United States. Western Union lines were built across vast stretches of near wilderness; spanning the great plains and the mountains. Telegraph stations were created in the cities, the towns, the villages, the tiny hamlets, at United States Army posts and at lonesome, isolated junctions across the continent. While the technology of that day was not sophisticated by today's standards, many engineering milestones were required in the construction of Western Union's system of lines. While the terms "Quality Assurance" were not commonly known, the engineers and construction crews did the best job with the tools of the trade the 1800's had to offer. As an example, the Western Union long splice is still the standard, even today, wherever superior wire lines are built.

Still, instead of the word "quality" several other words have been used to describe Western Union's services:

> "Reliability" when the telegrapher delivered a message in the wee hours of the morning or when the line crews battled a raging blizzard to keep the lines in service.
>
> "Courage" when the Western Union messenger delivered his message to the Army Post when hostile Indians were about.
>
> "Responsible" in the handling of financial and other confidential traffic.

As the demand for service grew and the technology of communications advanced, Western Union changed the configuration of its plant and introduced such devices as repeaters and switches for more efficient transmission. Still, Western Union's quality was largely determined by the reliability of its people.

An expanded Quality Assurance program has been initiated at Western Union which will assure Our Customers ever increasing reliability in Our Services.

Advanced systems such as GSA, AUTODIN, SICOM and INFO-COM have work elements which required specialized engineering dealing with overlapping disciplines such as Transmission, Switching, Terminal Equipment and Computers. To support these disciplines a Quality Assurance system has been developed at the new Technology Center at Mahwah, N. J. Some of the engineers involved in developing this system are shown in Fig. 1.

Quality Assurance may be divided into four major areas: Performance Control, Reliability Control, Quality Control and Configuration Control.

1) PERFORMANCE CONTROL

Performance Control is the establishment of the Company's technical performance objectives. Engineering, with the Marketing Department establishes the overall customer requirements. These customer requirements are translated into technical terms and values are assigned to each parameter. Responsible engineering activities establish the performance objectives for each equipment, system and service. These objectives are compared with the system specifications.

Execution of Performance Control assures that those elements of quality including reliability, maintainability, and operability are incorporated in the design of each equipment, system, and service.

In the absence of positive feedback, control can only be assumed. To give this positive feedback to the function of Performance Control, it is required that the system must be challenged. The information derived from these challenges is called Quality Audit. Quality Audit encompasses the following functions:

a. Design and develop or select equipment to continually challenge existing in-service systems.
b. Order the information derived from the system challenges.
c. Codify and reduce performance data from all sources.
d. Integrate performance data and analyze performance to determine the quality of service.
e. Periodically report the measure of the system's performance. Identify performance patterns and pinpoint problem areas.

2) RELIABILITY CONTROL

Reliability Control is further subdivided into its two principle functions, Reliability Projection and Reliability Analysis.

A Reliability Projection establishes reliability objectives for each new design so that when the new equipment is put in service, it will meet the overall Western Union objectives.

Reliability Analysis, establishes and publishes failure data effecting the elements making up the entire Western Union plant. As failure data on units in service becomes available, the prior figures are updated to reflect the actual experience. The engineers involved preserve and analyze failure experience data to yield an increasingly better base for future reliability projections. These efforts are coordinated with the Technical Facilities Department so that the field data collected in the EDITS Program is reduced to yield a data base for reliability calculations. Further, the reliability specialists establish failure patterns from field data, customer reports and test results for corrective action and prepare periodic reports on the reliability performance of Western Union facilities.

Figure 1—Some Engineers associated with the Quality Assurance Group at Western Union's Technology Center located in Mahwah, N.J., from left to right F. M. Fink, G. J. Svarczkopf, D. Carpenter and M. Y. Montemurno.

3) QUALITY CONTROL

Quality Control, by its nature, has traditionally been the province of manufacturers. Western Union is vitally concerned with this area of Quality Assurance both as a producer and a large user of manufactured articles. Inspection of manufactured items takes place both at the vendor's plant and in Western Union's production. Inspection must be done against uniform standards and the specific requirements of each end item. To provide guidance for Western Union's inspection department and to lead the company's testing activity, a Quality Control function has been recognized to guide in inspection in the following areas:

a. Establishment of minimum requirements for the inspection of material received, material in process, production of sub-assemblies, wiring and cabling, fabrication of parts, and assembling of units.

b. Qualification of manufacture. Establish the rules of test and inspection to prove that the production under conditions of normal manufacture preserves the performance characteristics of the equipment within pre-established limits. This examination may include, as required, environmental tests, reliability demonstrations and system integration tests. When the number of units being produced is large, or of a particularly critical nature, it may be necessary to have requalification performed periodically throughout the production to assure that the manufacturing tolerances are being maintained within the established limits.

c. End item inspection. In many cases it is necessary to inspect the end item after it is ready for delivery. Engineering will establish the criteria for this final inspection and assure that a specification is available to Materials Management Department.

d. Sampling. Where large scale production of relatively simple units or assemblies is in process, it may not be necessary to perform more than a cursory inspection of each produced unit. However, to assure uniform quality, it is necessary in such cases, to sample the production on a predetermined routine basis and to give the selected unit a thorough inspection. Engineering Quality Control must specify: the standard inspection criteria, the thorough inspection criteria and the sampling procedure.

The Test and Evaluation engineers within the P&EO Department, in conjunction with Technical Facilities Department, Material Management Department, and Public Office Operation assure the preparation of test plans and procedures for tests on new equipment, systems, and services. The Test Plan formally defines, in engineering language, the conduct of each test. These plans include:

a. objective of the test
b. method of accomplishing the test
c. conditions for test
d. time and place of test
e. responsibility for test
f. test criteria

This Quality Assurance system guides the design engineers in the preparation of detailed test procedures. The Test and Evaluation system establishes guidelines for the conduct of breadboard and prototype testing and the analysis of the test data for the test report. With the Inspection Department, the Design Engineering section will conduct manufacturer qualification testing and with the Technical Facilities Department, conduct field tests, analyze the data and report the results. This system helps the responsible engineer to design and develop test configurations and test setups to accurately confirm the performance of Western Union's plant.

4) CONFIGURATION CONTROL

Configuration Control is the regulation of the equipment of the company. Each stage in the life of equipment from inception to salvage is carefully documented. The identity of each unit is recorded as well as its physical location and the use to which it is put during its life. The model, vintage and status of modification of each unit of plant is accounted for. The working of its components and the unit's performance within complex systems or services is recorded and analyzed for experience in new design efforts and, when warranted, corrective action. The Configuration Control function may be divided into two areas: Documentation Planning and Configuration Management.

Documentation Planning establishes the formats for Western Union technical documents. The prepared documents are reviewed to assure that they are complete and in accord with Western Union standards and the planned formats. Where deviations are necessary, the reason for these deviations are recorded: The format and general con-

tent for the following types of documents have been established in the Quality Assurance Manual:

a. Technical Policies & Procedures

b. System Specifications

c. General Specifications

d. Design/Development Specifications

e. Performance Specifications

f. Procurement Specifications

g. Manufacturing Specifications

h. Test Specifications

i. System Manuals

j. Technical Reports

A Flow Chart showing the steps in the procedure is shown in Figure 2.

Configuration Management defines the procedures by which are set up and new practices, existing practices, such as numbering plans, family trees for drawings, specifications and manuals, distribution of equipment and associated documentation, and record system to account for all items under Configuration Control. The practices will provide information for reliability analysis to identify failure patterns within classes of equipment and recommend corrective action, as shown in Fig. 3.

Engineering groups of P&EO, the Materials Management Department and Technical Facilities Department will implement the procedure governing the initiation of Engineering Change Requests, the processing of the change request and the preparation of Engineering Change Notices. They will assure that the Engineering Change Requests are acted upon and record the issuance of all Engineering Change Notices.

Technical Facilities Department will produce the procedures required to convert an Engineering Change Notice into an approved Change Order and, with Engineering, the procedures to document the change or supplement the existing field documentation.

The Quality Assurance system charts will advise and assist in the establishment of equipment accounting procedures so that the location of each piece of equipment as well as its current condition, including options and changes is recorded in a central location and available when required.

Interrelation of Line to Staff

Each task: the entry of a new equipment, the implementation of a system or the start of a new service, is performed in a similar manner. Engineers design or select the parts and plan the interworking. Material Management Department procures the pieces and arranges their delivery. Technical Facilities Department installs, cuts over and maintains the finished configuration. Marketing Department establishes future requirement and plans the necessary sales effort. The magnitude of the tasks may differ but basically each system is built in this way.

Corresponding to each of these line functions, there are available to the line organizations, staff assistance from specialists. The relationship between several line organizations, and some of the staff services available, is shown in Figure 4.

We have chosen to divide Quality Assurance into four functional systems as shown in Figure 5:

- Performance Control

  The establishment of objectives, limits, and the methods of adjudging system satisfaction. The functions of Performance Control are illustrated in the Flow Chart in Figure 6.

- Reliability Control

  Reliability Control is the tool used in design to predict a quality of service and the procedures of analysis used to help determine problem areas for corrective action. Figure 7 is a Flow Chart showing the inputs from the Reliability Control System.

- Configuration Control

  Configuration Control accounts for the current status of equipment including equipment documentation.

- Quality Control

  The guidance provided for inspection and qualification of equipment to be placed in service, as well as the periodic testing requirements necessary to assure continuing system performance.

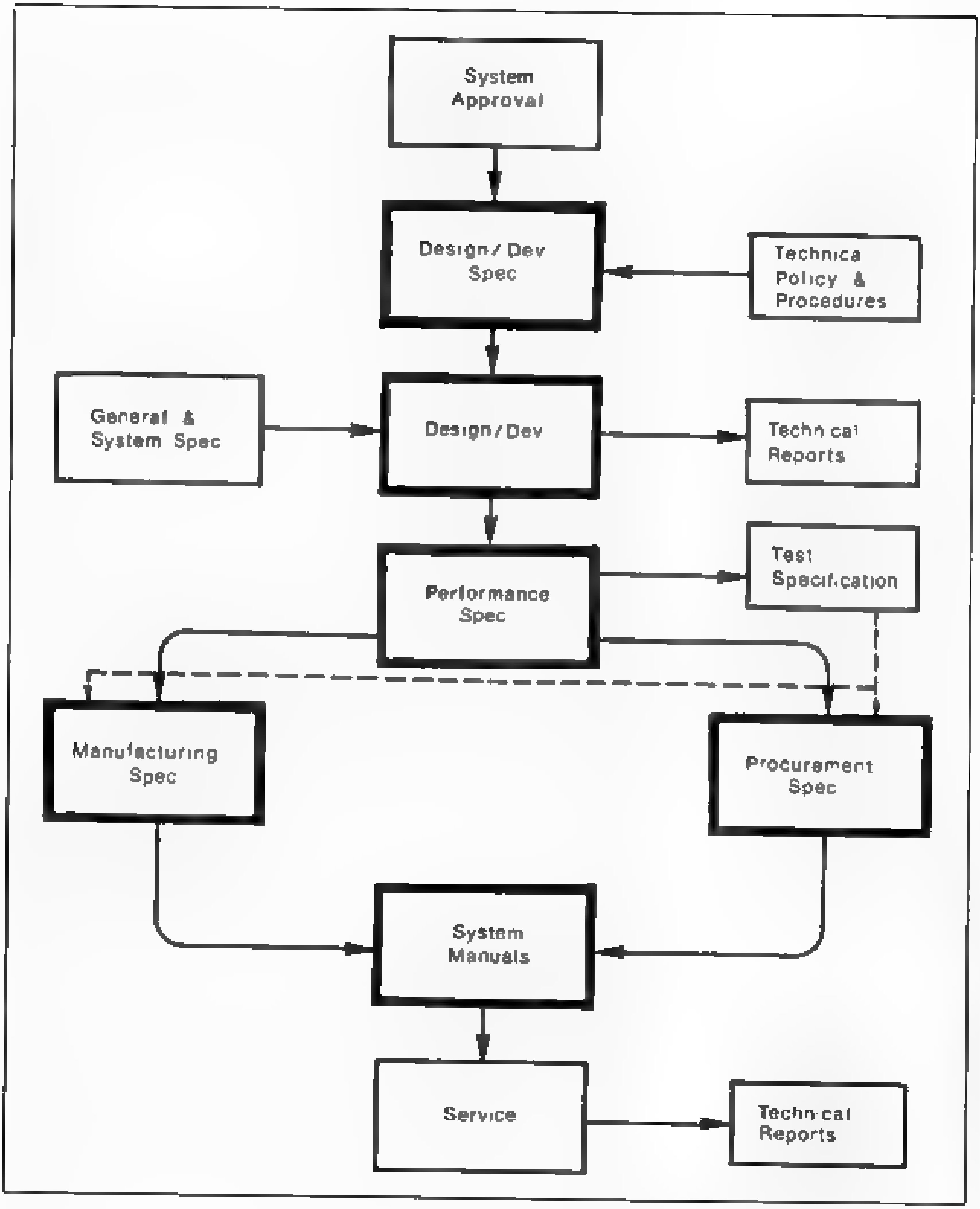


Figure 2—Flow Chart for Documentation Planning.

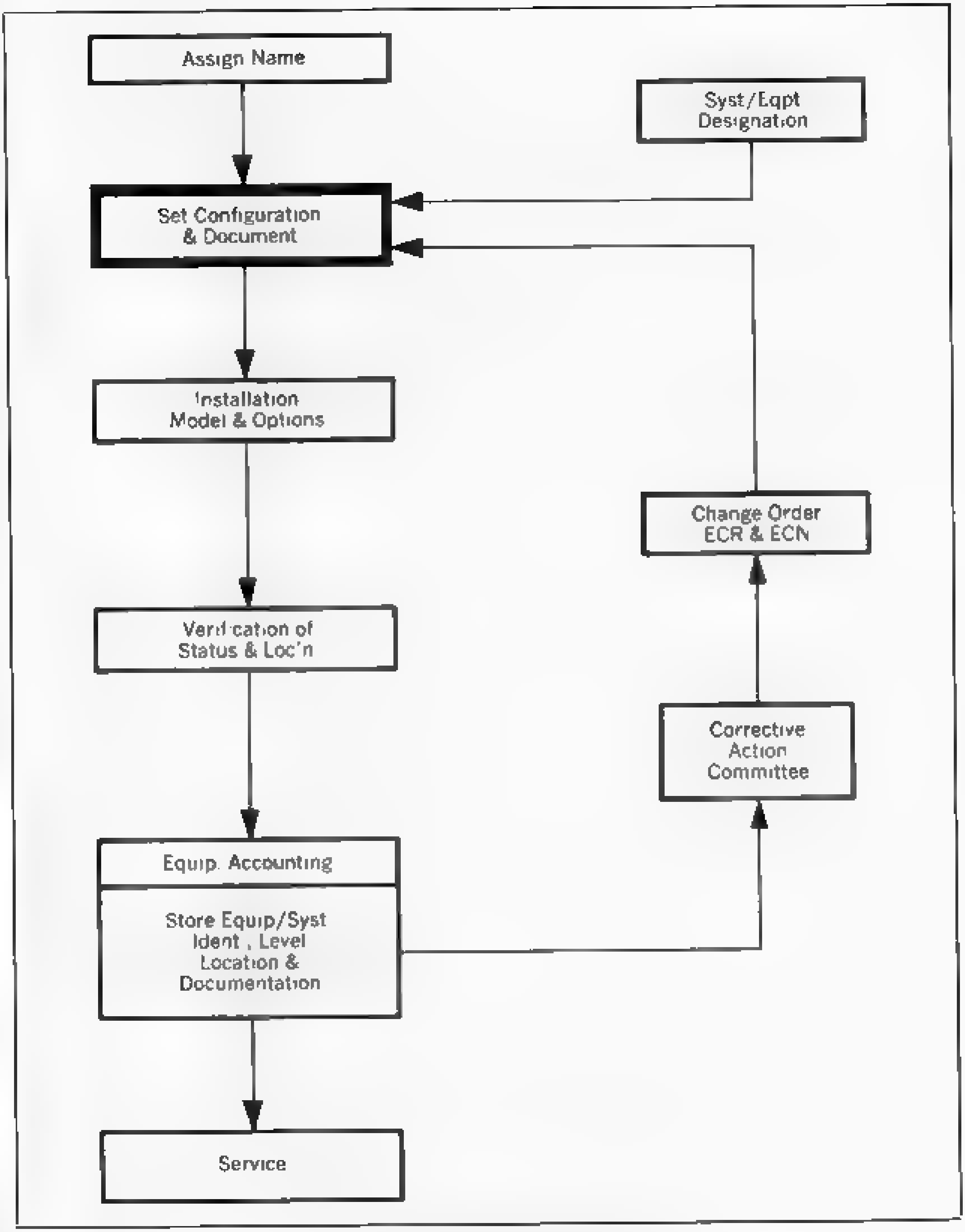


Figure 3—Flow Chart for Configurations Management

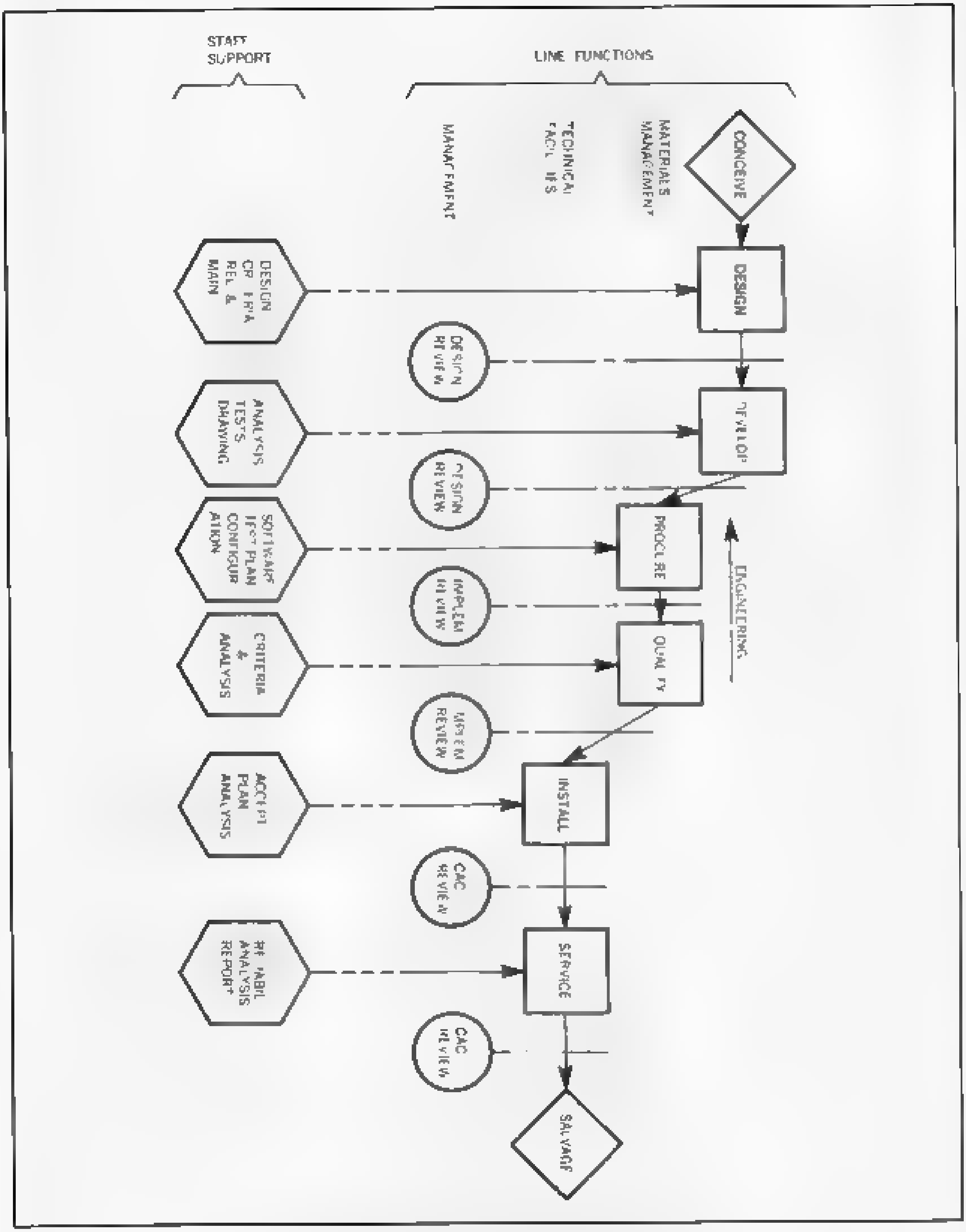


Figure 4—Relationship of Line Organization to Staff Services

Figure 5—Quality Assurance Make Up

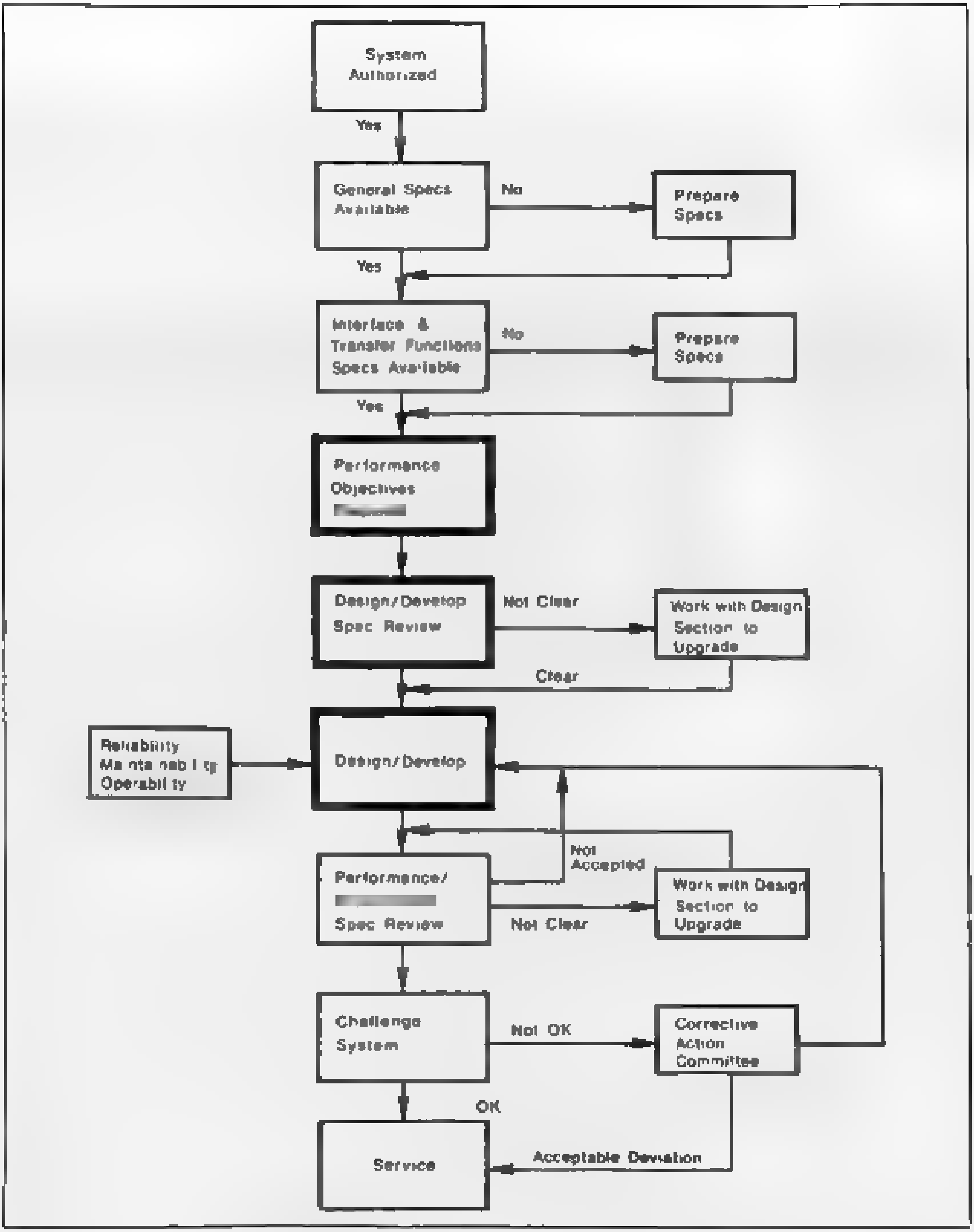


Figure 6—Function of Performance Control

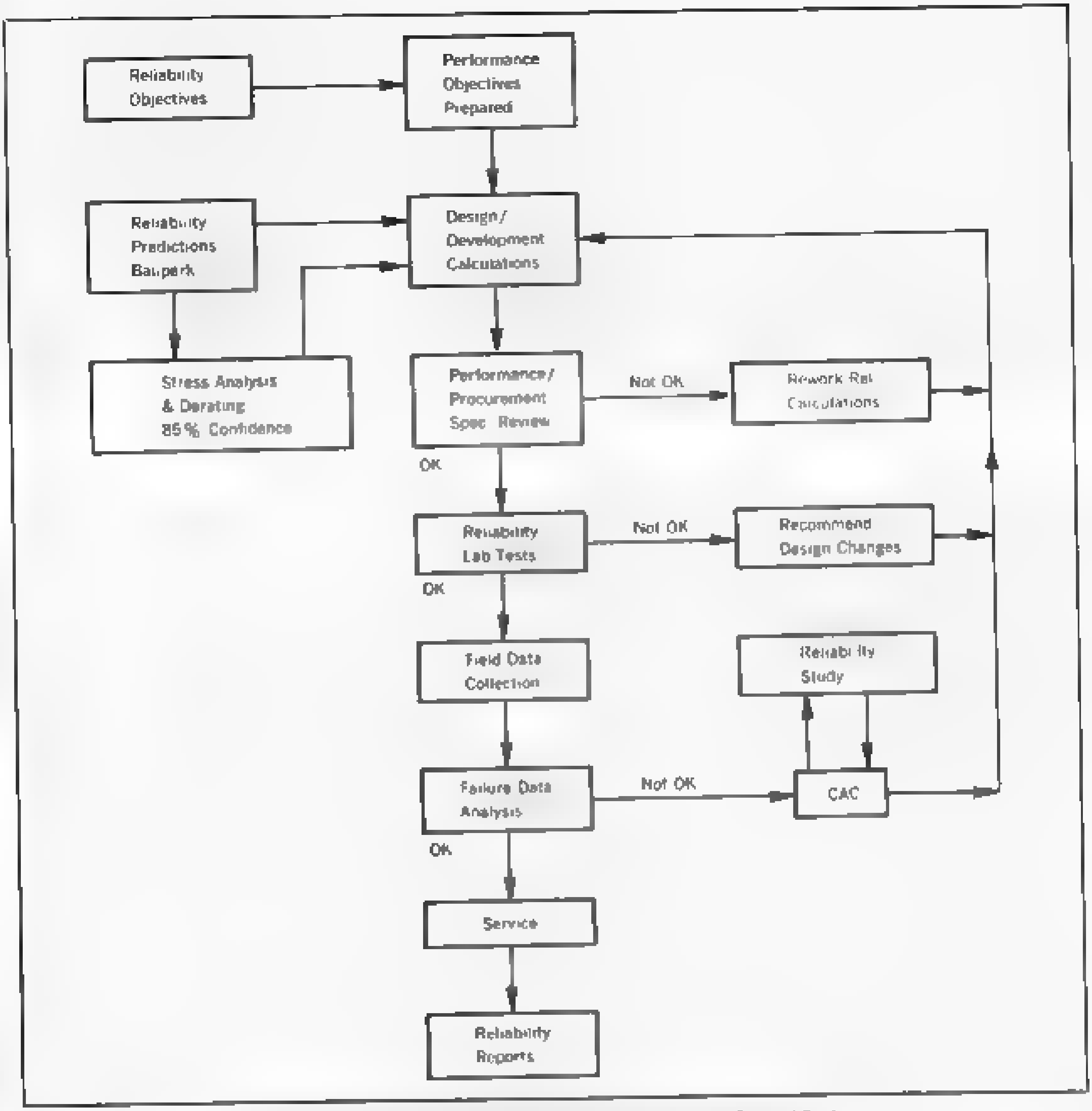


Figure 7—Flow Chart Showing Inputs from the Reliability Control System

New Emphasis

Western Union is placing new emphasis upon the technique of Quality Assurance. The system for Quality Assurance has been developed to support Western Union's objective to provide superior service. This program makes the technical status of each equipment system or service continually visible to higher management. The engineering portion of the program has been documented in the Quality Assurance manual. That this recently distributed volume may be used through the company, provision has been made for the inclusion of sections generated by the other line organizations: Marketing, Technical Facilities, Material Management and Public Office Operation. In addition, a Quality Assurance Glossary is incorporated in the manual to more specifically define the meanings of Quality Assurance terms as they will be used within Western Union ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■

System Performance in Communication Systems

George J. Svarczkopf

Systems Goal

A primary goal of a communication system is performance that is 100 percent satisfactory to the customer. To achieve this end, Western Union continuously alters its existing plant so that many different services can be integrated into a single system. In this dynamic process, the plant is subjected to constant review; redesign parameters are determined; and the standards of system performance are maintained in the family configurations outlined in Figure 1. The family of specifications is composed of performance and general specifications. The performance specifications are prepared for the five major areas within Western Union, namely: subscriber terminal, exchange transmission, exchange switch, long lines transmission and long lines tandem switch. The transfer, interface and test functions for the various types of service, digital, voice (2- and 4-wire), facsimile or combinations of these are included in the performance specifications. This article deals with some of the factors that must be considered in achieving efficient system performance. From a study of all factors some measurable parameters may be ascertained which reflect the "quality" of the system.

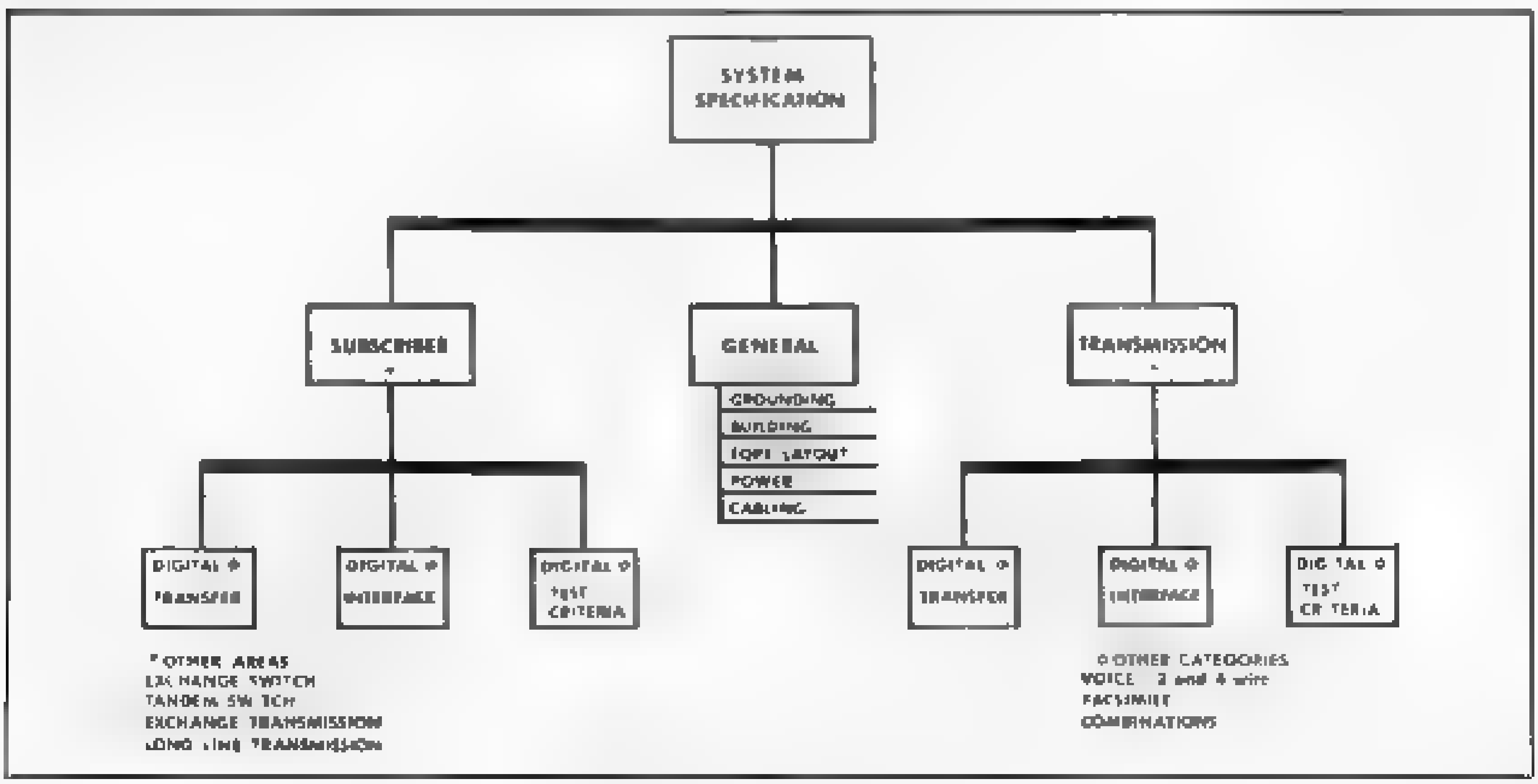


Figure 1—Family Configurations

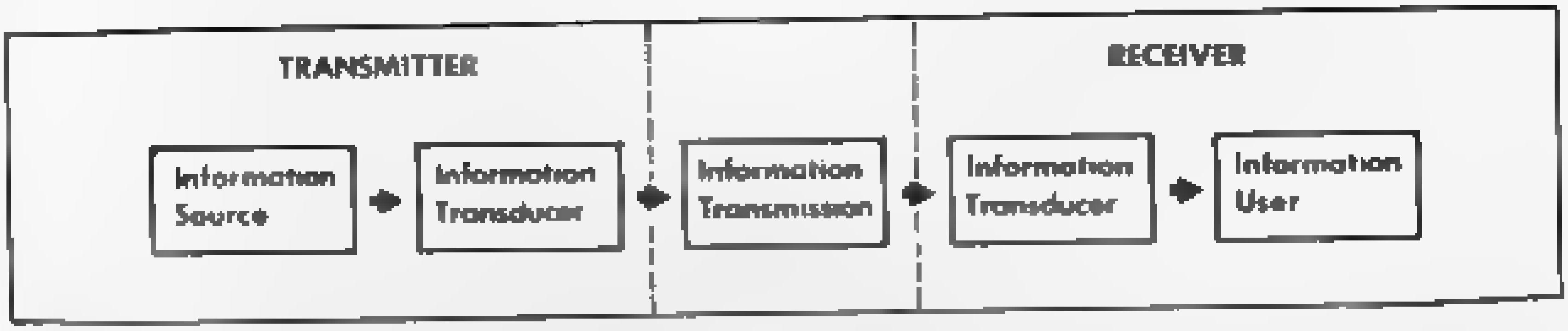


Figure 2—Basic Communication System

Communications, in Western Union, can be defined as the transfer of information from a source to a user. This transfer can occur within the immediate area or via a transmission media, if the source and the user are at some distance from each other. The media used to transfer information may be physical wires, as in telegraph and telephone — the air as in voice, or — electromagnetic waves as in radio and television. The transfer of information over any media, however, must be such that the receiver can reproduce the intelligence with an acceptable error. A very basic communication system, but one that applies to all types of service offered by Western Union, is illustrated in Figure 2. The elements within the source block may be a device capable of processing stored text matter, producing a sound, presenting a visual display, etc. Normally, the information from the source must be translated to a form that is recognized by the transfer media. This is the function of the transducer. One example of such a function is to change printed text to patterns of electrical energy.

The transmission facility consists of cable, switching, modulation, multiplexing and radio equipments necessary to transfer the information to a distant location. The reverse operation at the receiver reconditions the information into a form required by the user.

Background

Transmission of digital information has progressed considerably since 1844 when Samuel F. B. Morse sent the first public telegram. Originally, signals consisted of current-no-current over a single wire using ground (earth) as a return. In 1887 a switching system was invented which enabled the same transmission facility to be alternately used for the transmission of telegraph and speech information. Analog techniques derived for the mushrooming telephone network led to new methods of sending data long distances. Conversion of digital inputs to analog signals permitted the sending of multiple messages simultaneously over the same pair of wires. Much of the present Western Union plant is analog as witness the microwave and the amount of multiplex equipment. In recent years, however, the influence of the transistor has generated additional interest in digital transmission. Today, we are faced with an environment where digital information is transferred at speeds up to 1.5 megabits per second and above. Computer control routing of information allows users with different speeds and codes to communicate with each other. How do we assure that the quality of service will not only be satisfactory but also be constantly improving? Figure 2 was useful in identifying the general functions performed in the transmission of information, but it must be expanded to reflect the various subsystems which form the Western Union communication network. Present practice in establishing system objectives and limits is to establish a reference circuit and distribute the objectives and limits of significant parameters across it. A typical Western Union reference circuit is shown in Figure 3.

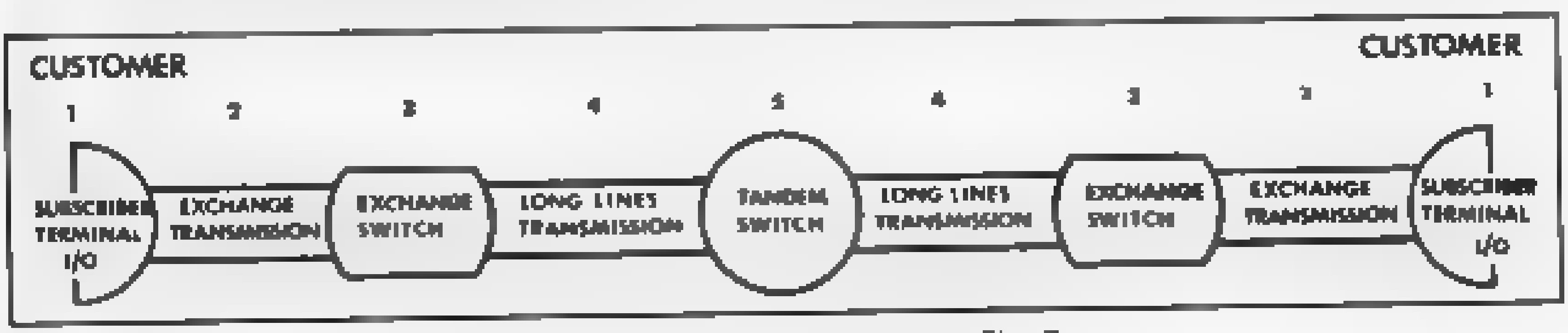


Figure 3—Western Union Reference Circuit

Procedure

Before any communication system is designed, the requirements must be determined according to the following questions.

- What existing facilities are available?
- What is the existing and projected volume of traffic?
- What geographic areas must be served by the system now and in the future?
- What are the service requirements?
- What will be the investment return and over what time period will this return be realized?

The projected objectives of a communication system are not necessarily limited by the configuration of the present plant. *Requirements* are determined subjectively by the user — the maximum amount of allowable distortion and interference is evaluated in terms of customer satisfaction. The ultimate objective for digital communication is to transfer the information with zero errors. The cost to achieve this objective using present techniques could be prohibitive. Therefore, present objectives of a communication system are usually a compromise and are set one magnitude above the current requirements and the current state of the art. The average error rate presently used as an objective is one error in every one million bits transmitted.

Significant Parameters

The factors affecting all types of information transfer are level, noise and distortion. Level is simply the amount of signal power. The noise and distortion factors may be classified according to the following:

(a) NOISE

Ambient
Impulse
Electrical Disturbance
Background
(Signal-to-Noise)

(b) DISTORTION

Frequency (Attenuation)
Amplitude (Non-linear)
Harmonic
Intermodulation
Delay (Phase)
Fortuitous

Noise

(1) Ambient noise is environment noise in the same room as the transmitting source. This noise may be random or periodic, and depends upon the characteristics of the noise source. This type of disturbance is only troublesome if the transmitting transducer changes the original noise to electrical energy.

(2) Impulse noise may be defined as a series of isolated pulses of very short duration. The component frequencies are so phased with respect to each other that their amplitudes add arithmetically at the instant of occurrence of the pulses. It is introduced into the system by electrical or magnetic coupling from an external or internal source such as contact closures, lightning, and off-on operation of electrical motors. Impulse noise accounts for a substantial portion of the errors occurring in a digital signal.

(3) Electrical disturbance is defined as noise generated by atmospheric conditions and it may be random or periodic.

Background noise is the sum total of all the above types of noise. It is usually expressed as noise power and related to the signal magnitude as a signal-to-noise ratio.

Distortion

Another factor affecting the transfer of information is distortion, defined as an undesirable change in the wave form. Distortion is basically a characteristic of equipment design and as such, can generally be controlled by the use of compensating networks or the selection of higher quality parts. The various types of distortion are frequency (attenuation), non-linear, delay, harmonic, intermodulation and fortuitous.

Frequency (attenuation) distortion is a change in signal from a uniform amplitude over the frequency range required for transmission.

Non linear distortion occurs when the ratio of voltage to current, using the root mean square values is a function of the magnitude of either element. This form of distortion is also called amplitude distortion.

Harmonic distortion is a form of non-linear distortion in which harmonics of the fundamental frequency are generated by the non-linearities of the equipment.

Intermodulation distortion results from the cross coupling or leakage of carrier or signal energy from adjacent facilities. It usually occurs when excessive signal levels are present or when there is insufficient attenuation of the undesirable sideband energy.

Delay distortion occurs when the phase angle response of the transfer impedance is not linear with frequency within the desired range. This results in a time delay of transmission which varies within the usable frequency range. This type of distortion is sometimes called phase distortion.

Fortuitous distortion affects pulse type transmission and results from random causes that may shorten, lengthen or delay individual or a series of pulses.

Establishing the Reference Circuit

Current practice is to distribute the above factors across a working reference circuit. At present the working reference circuit as shown in Figure 3 is being established for the overall Western Union Communication plant. It consists of five major sub blocks — subscriber/terminal, exchange transmission, exchange switch, long lines transmission, and the tandem switch or long lines switching. Values for the significant parameters discussed above will be assigned to the overall circuit and from these will be generated the intermediate values for the sub-blocks. The values assigned for each parameter are expressed in a manner whereby a maximum and a minimum limit is quoted where possible. Whenever a range is not applicable the appropriate plus or minus limit is noted. The type of information considered is digital, analog and facsimile. Since the methods applied to each are similar, only the transmission of digital information will be discussed here.

Level

The reference circuit will make use of a Reference Test Level Point (RTLP). It will be established at a point between the talking subscriber and the associated exchange office. This point will also be considered as zero level. If a 1000 Hertz, one milliwatt test signal is injected at this point and the impedance of the circuit is 600 ohms, a high input impedance VTVM, whose meter face is calibrated for a 600 ohm dB scale, would measure the test tone as a level of 0 *dBm*. All traffic levels or secondary test tones are expressed in a dB value either above or below the level of the reference test tone at the reference test level point. If a secondary test point differs from the RTLP by 16 dB of attenuation, the reference level test tone would be measured at a value of −16 dBr. Therefore, this point is established as a −16 dB TLP. The traffic level at the −16 dB TLP in today's plant is 15 dB below the test tone level or −31 dBr, which can also be expressed as −15 dBm0. The relationship of the reference test tone and the traffic signal of −15 dBm0 is constant any place in the reference circuit.

For an error performance of 1 in 10^5, considered satisfactory by the present user, the final signal-to-noise ratio should be approximately 20 dB. Equipment placements to improve error performance must be carefully considered where the original equipment still has useful life.

The problems as related to signal level may be summarized:

a. Should the equipment be changed to increase the signal level?

b. Should the noise level as transferred by the equipment be reduced?

c. What stability should be maintained to transfer digital data at speeds of 2400 baud and above?

d. Should the transmission facilities be changed to all digital transfer of information?

These questions are currently being studied in detail at Western Union and the answers will be reflected in the performance specifications of future plants.

How Noise Affects Communication

Noise is by far the most harmful factor affecting effective communication especially in today's world of digital data transmission. Particularly serious is impulse noise whose magnitude is random and whose frequency may range over several octaves. The cause of impulse noise is quite difficult to identify and its specific effects on digital transmission is still under study

Western Union has instituted two separate test programs related to impulse noise. The goal of the first was to measure the amount of impulse noise that is representative of the Western Union plant.[1] The second program was established to determine the effects of this impulse noise on 2400 baud digital transmission. Western Union has found that on all circuits tested that the curve of impulse noise amplitude vs. counts per minute always followed the same form. Fitting the curves to the following power series.

$$\sum_{n=0}^{\infty} a_n x^n = a_0 + a_1x + a_2x^2 + \cdots + a_nx^n + \cdots$$

for a finite number of terms, they can be written as
$y = ax^n$.

One test provided data which fit an exponential curve $y = ae^{kx}$. This is a special case of the general form of a power series where $y = y'$

$$y = a_0 + a_1x + a_2x^2 + \cdots + a_nx^n + \cdots$$

$$y_1 = a_1 + 2a_2x + 3a_3x^2 + 4a_4x^3 + \cdots$$

$$+ (n+1)a_{n+1}x^n +$$

when $y = y_1$, the coefficients of both equations must be equal, therefore

$$a_1 = a_0, 2a_2 = a_1, 3a_3 = a_2, \cdots (n+1)a_{n+1} = a_n, \cdots$$

Let $a_0 = c$,

then $a_1 = c, a_2 = \frac{c}{2}, a_3 = \frac{c}{2.3}, \cdots a_n = \frac{c}{n!}, \cdots$

and for $c = 1$

$$y = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \cdots \frac{x^n}{n!} + \cdots = e^x$$

The data fit the equation $y = ae^{kx}$.

For all test data taken, the 3 count per minute rate appeared to lay on or very near the knee of the curve. Assuming that this is generally true for all circuits, this count rate can serve as a convenient reference point to make comparisons between different circuits. By determining the level at which the count rate is 3 counts per minute and then locating one point above and one below the 3 cpm point, the curve is sufficiently well defined to analyze a particular circuit.

The maximum allowable impulse level for the 3 cpm reference is based on the susceptibility of present data modems to this type of interference. To assure a signal impulse noise of 18 dB minimum (at 3 counts/minute), the reference level is 57 dBrnO derived as follows.

Signal (db) − Noise (db) = 18 db

or Noise (db) = Signal (db) − 18 db

= (−15 dBmO) − 18

= −33 dBmO or 57 dBrnO

The second test program will be described in another article in this issue Winter 1969 of the TECHNICAL REVIEW. The test portion of the program has ended and the data is being analyzed. At this time it has been confirmed that the Western Union transmission facilities between New York and Chicago effectively transmit 2400 baud digital information, with an average error which approaches the current objective of one error in every 1,000,000 bits transmitted. The collected data reveals that the majority of the errors over this facility can be attributed to momentary dropouts and impulse noise. Bit error performance would improve by one order of magnitude if the effects of the momentary system dropouts and impulse noise could be excluded.

The complete analysis of the test data to verify the above numbers will aid in the establishment of system objectives and limits as related to impulse noise and digital data transmission.

How Distortion Affects Communication

All six types of distortion affect the transfer of digital information and each must be considered in the system performance specifications. Frequency (attenuation) distortion limits are usually expressed for the band between the lower and upper cutoff frequencies and using 1000 hertz as a reference for audio. Various tests have been con-

ducted to determine the effect of limited bandwidth on transmission. The CCITT Red Book, Volume V, documents the results of the tests. The tests produced a curve which has the equation of $y = 2(3.7\ f)^2$, where y is the transmission impairment in decibels and f at which the loss of a circuit is 10 db greater than the loss at 1000 Hz. Transmission impairment is the amount of effective loss which is caused by the reduced bandwidth.

The allowable frequency (attenuation) distortion for the overall reference circuit could be derived using the above curve to determine the cutoff frequency and then establishing the slope of the attenuation curve for the number of sections connected in tandem.

Envelope delay distortion has very little effect on the transfer of analog signals but has a great deal of effect on the transfer of digital information. However, as the word "envelope" implies, it is not the absolute delay, but the difference in the velocity of propagation at the frequencies in the spectrum of the transmission facility which is important. Today's transmission facilities usually are referenced to a frequency range of 300 Hz to 3400 Hz, and the center frequency for delay distortion is considered to be 2000 Hz. Delay distortion is usually expressed in microseconds as removed from the center frequency.

The maximum amount of delay distortion permitted in a transmission facility is basically fixed by the digital information transmission speed and the slope of filter characteristics. During the design of a transmission facility, the engineer must consider that delay distortion usually accumulates on an arithmetical basis, ±10 percent, and therefore should design all filters slopes so the overall distortion does not exceed the limits fixed by the maximum baud rate of the digital information to be transferred. In some cases, other factors related to bandwidth restrict the linearity of the slope of the filters. When this occurs, envelope delay compensation networks are incorporated into the transmission facilities to maintain the overall envelope delay distortion limits.

Fortuitous distortion is caused by random deviations of the circuit elements which may change the size or shape of the original pulse signal. As the speed of digital information is increased, the range of limits for this distortion is decreased due to the reduction of available pulse time. The advent of the solid state devices with their nanosecond response times has aided in reducing the effects of fortuitous distortion. Today receivers and/or regenerative repeaters are designed to detect a digital signal which has been distorted from the original size and shape by approximately 45 percent. These devices will reproduce the signal to approximately zero distortion.

Challenge

Once the system specifications are produced and the limits for the parameters are established, the system must be challenged (tested) to determine if the parameter limits are being met. If system performance is the ultimate goal for a communication system, the challenge phase (or test) becomes as important as the design and the communication equipment. An effective challenge program should consist of test criteria, test plan, test procedure and the testing of the facility. The test criteria should include a general description of the types of tests to be performed, types of test equipments to be used and the limits of acceptability for each type of test. The test plan should state the sequence of tests and the environmental conditions for the tests. The test procedures should specify how the tests are to be performed. The final phase of communication system performance is the evaluation of the system from the collected test data. The test data should reveal how good the system design is, what problems should be corrected and what, grade of service as related to availability and reliability, is being supplied to the user.

Summary

Figure 3 suggests that the Western Union Communication system is segmented into five general sections. The equipment included in these sections must function together as a single system to achieve a performance that is satisfactory to the user. To determine the overall performance the performance for each section must be evaluated. Then by mathematical combination, the results can be expressed as system objectives or current limits in the family of specifications.

For each service, system segment or system, an objective, towards which Western Union will strive, is established. Similarly, against each parameter, effecting the performance, a limit of acceptability to which the entity can be tested is set up. While the objective may not now be obtainable because of the economies involved or the "state of the art" does not permit, the limits must be met in all cases. In the event the limits cannot be achieved and the trouble appears to be limitation of equipment, a redesign is required. ■ ■ ■ ■ ■ ■

Configuration Management at Western Union

D. J. Carpenter

For many years problems of equipment change were easily resolved. Most field and internal equipments could be readily modified because they were simple and relatively unsophisticated. Because of the pressures for rapid change and management's need to know the status of change immediately many electronics companies now use a system known as Configuration Control or Configuration Management as an answer to this need. Knowledge of reasons for change, how the function of the equipment is affected by a change, provides management with effective evaluation of performance. It is for these basic reasons that the Configuration Management program has been set up at Western Union.

The purpose of this article is to describe one way Western Union effects control over the configuration of its systems.

Configuration Management Concept

Configuration is defined as "The figure, contour or pattern produced by an arrangement of parts." In a more technical sense, Configuration is the arrangement identification and location of parts and equipments within a system. "Configuration Management" is therefore the management of the technical arrangement, identification and location of parts which define a system, system equipments, and the management of the changes to be made within these systems or equipments. The successful workings of such a system require procedures by which mutually supporting and uniform methods are established. These interrelated methods are usually called *Configuration Identification*, *Configuration Control* and *Configuration Accounting*. To establish and maintain these procedures in a company such as Western Union is the responsibility of Configuration Management.

In the past decade, the growth of more complex systems, the impact of the digital computer, and the advance of solid state technology have caused major changes in business. The need for improved performance, reduced cost, and increased volume production, resulted in rapid changes in the telecommunications industry.

Fortunately, the methods and procedures used to document the effects of change had been carried over into the electronics industry from the aircraft industry. However, the need for rapid analysis and the need for preparation for change, required that all facets of management become aware of the change requirements. A unilateral change by the engineering department is meaningless if the component part is unavailable or can not be purchased in sufficient quantity by the Purchasing department. To integrate these demands, management's usual approach is to establish a forum. Responsible members of all the related company functions must concur on the best possible action and direct this action toward company goals.

The coordination of the above actions, which make up management decision to change, is called Configuration Management. Western Union has made significant progress in this area of management. The System Analysis Simulator, described in the Autumn 1968 issue of the TECHNICAL REVIEW as a Management Tool to Evaluate the Dynamics of change, develops a model which allows changes in configuration to be set and the results of this change evaluated.

Reference Point or Baseline

The Western Union points of reference across the system life cycle have been established to determine when you start These points of reference are used by the management review teams. The purpose for these reference points is to provide continuity and establish traceability for management. These points are called "base lines" and are defined by the formal release of documentation. The location of four of these base lines across the life cycle of the system or equipment, are shown in Figure 1

The design of a configuration is made from requirements, available design criteria and known test evaluation data. This information is available from Western Union personnel. As these requirements become more firm and coherent through discussions with the management team, the identification of a particular configuration is made

A system or equipment specification for either procurement or manufacture is developed and approved. In support of this specification, a List of Materials is drawn up for machine processing. This document, otherwise referred to as the "family tree" establishes the hierarchy of the system hardware elements. The List of Materials is also a point of reference, and can be used to measure progress toward the ultimate use of the system or hardware In Configuration Management, this is the framework or skeleton that establishes the identification of the configuration. The IDP part numbers for hardware parts, interconnecting cables and other equipment, are listed on this form. The list is a breakdown of each piece of equipment and part into its particular subassembly and is used as a check list in configuration control activities

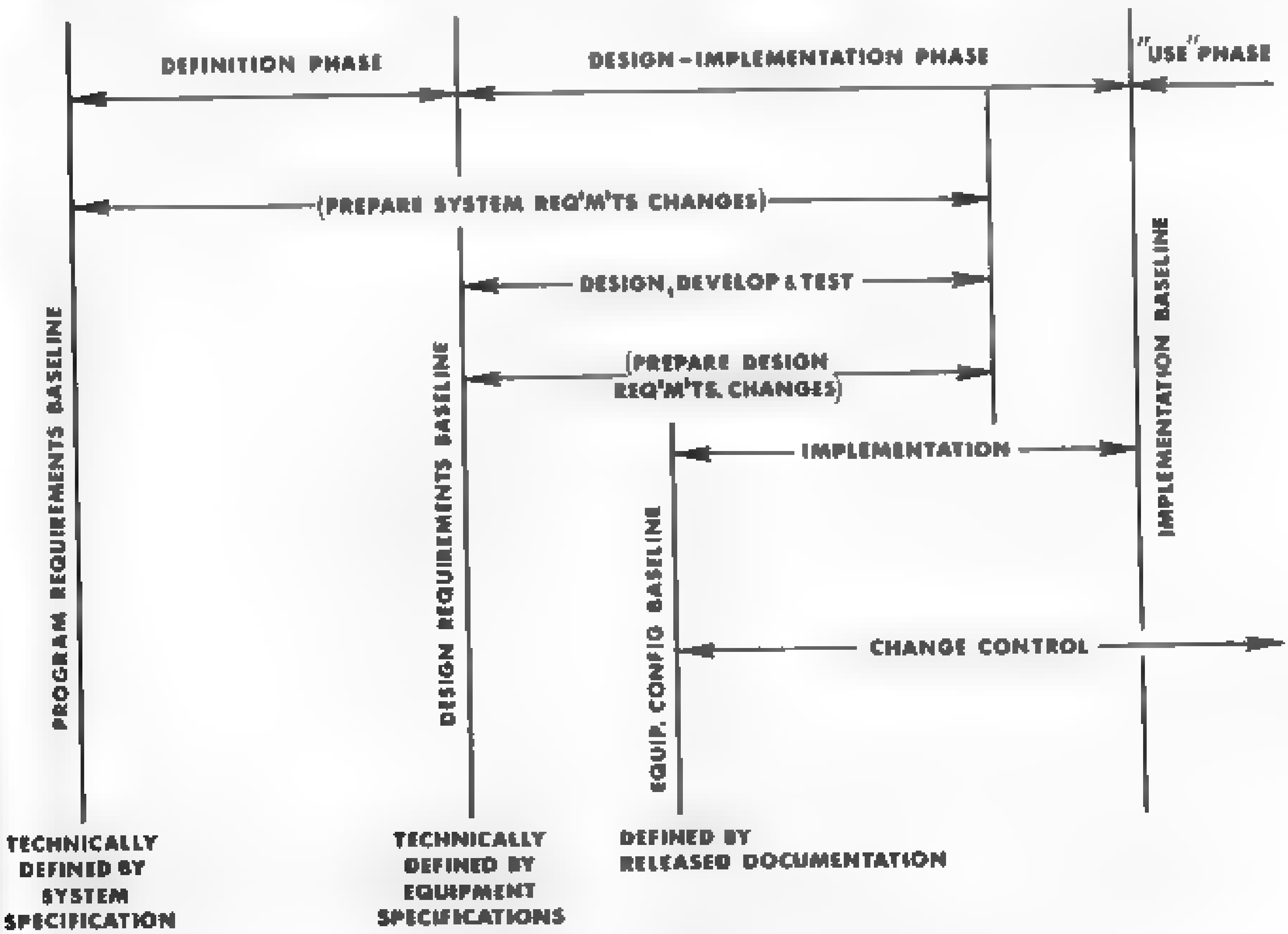


Figure 1 — Life Cycle of a System Showing Four Critical Baselines

Objectives of Configuration Management

The objectives of Configuration Management are:

a. To provide managers at all levels with sufficient information for making appropriate, timely decisions during development, implementation and operation of a system.

b. To attain maximum economy in configuration management data, forms and reports.

c. To provide a system for use in the control of design engineering that will:

1. Increase the effectiveness of standardization
2. Support project definition

d. To help evaluate a proposed configuration change and thoroughly consider the change's total impact on cost, operational capability, and support these by adequate hardware and documentation.

e. To promote the efficient and timely implementation of all the aspects of the approved change.

Configuration Identification

There are three basic reasons for an identification system. The first is that it is desirable to know the location of Western Union equipment within the configuration. Secondly, the identification system should identify each piece of equipment from the standpoint of design, installation, and during "field merge" when equipment may be recombined. Thirdly, to permit the automation of the configuration for management control and reporting. The Program Manager designates the location and equipment model numbers of his system. When equipment is under Western Union design engineering control, the cognizant design group will provide a breakdown by assembly level of each piece of equipment that is subject to change control. When equipment is purchased, the Project Manager will designate which parts of a unit are the lowest level subject to change control and status reporting. Identification is automated by coding a multidigit field for serial number, type designation, model number, location, etc., as shown in Fig. 2.

Configuration Control

Configuration control is change control and provides that all changes to baseline, specification and system/equipment be formally approved and documented. Engineering Change Notices are required for the following changes: 1) Any change in the approved specification which technically defines the program requirements baseline, 2) any change in the detail specification which affects the design requirements baseline, and 3) any change which affects the equipment configuration baseline. Figure 3 illustrates the Engineering Change Notice. These changes are processed by three different review committees.[3] The review committees are responsible for the review and recommendation for approval of the Change Notice. In addition, these committees immediately respond to emergency change requirements by the contractor, or the field. The committee assures that such changes are held to a minimum, and are consistent with safety and overall effectiveness of the system, the equipment, or the facility concerned.

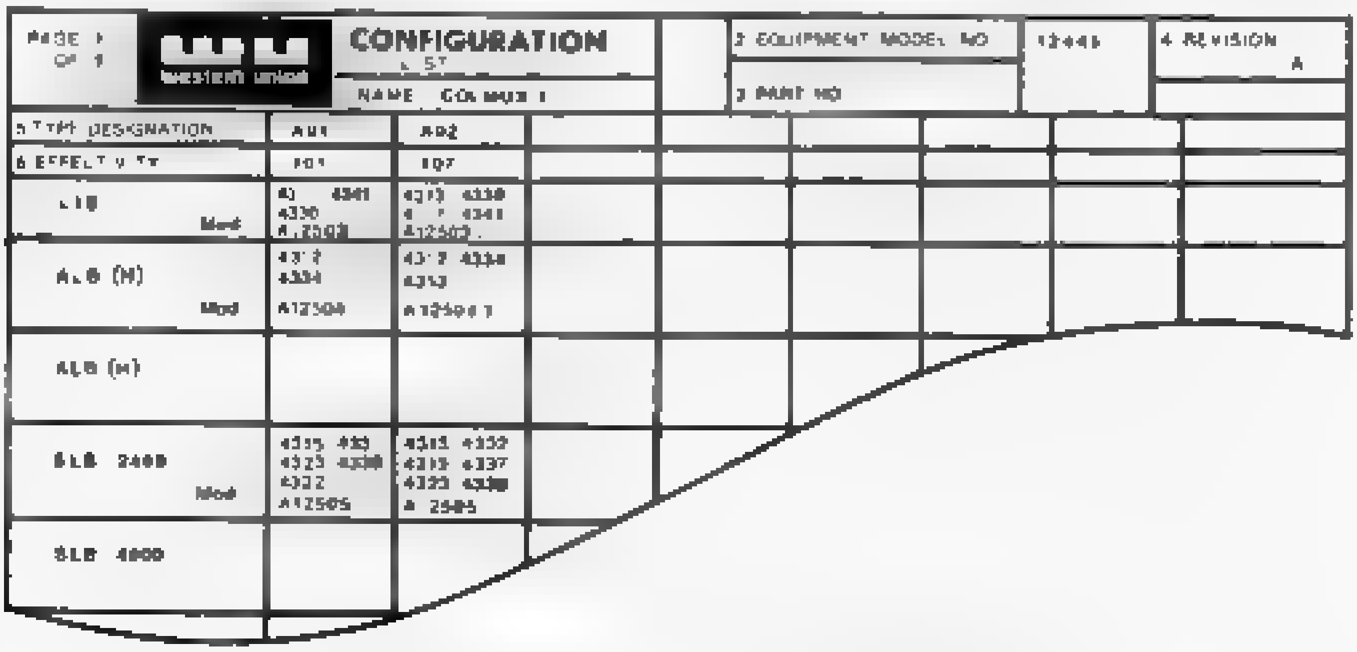


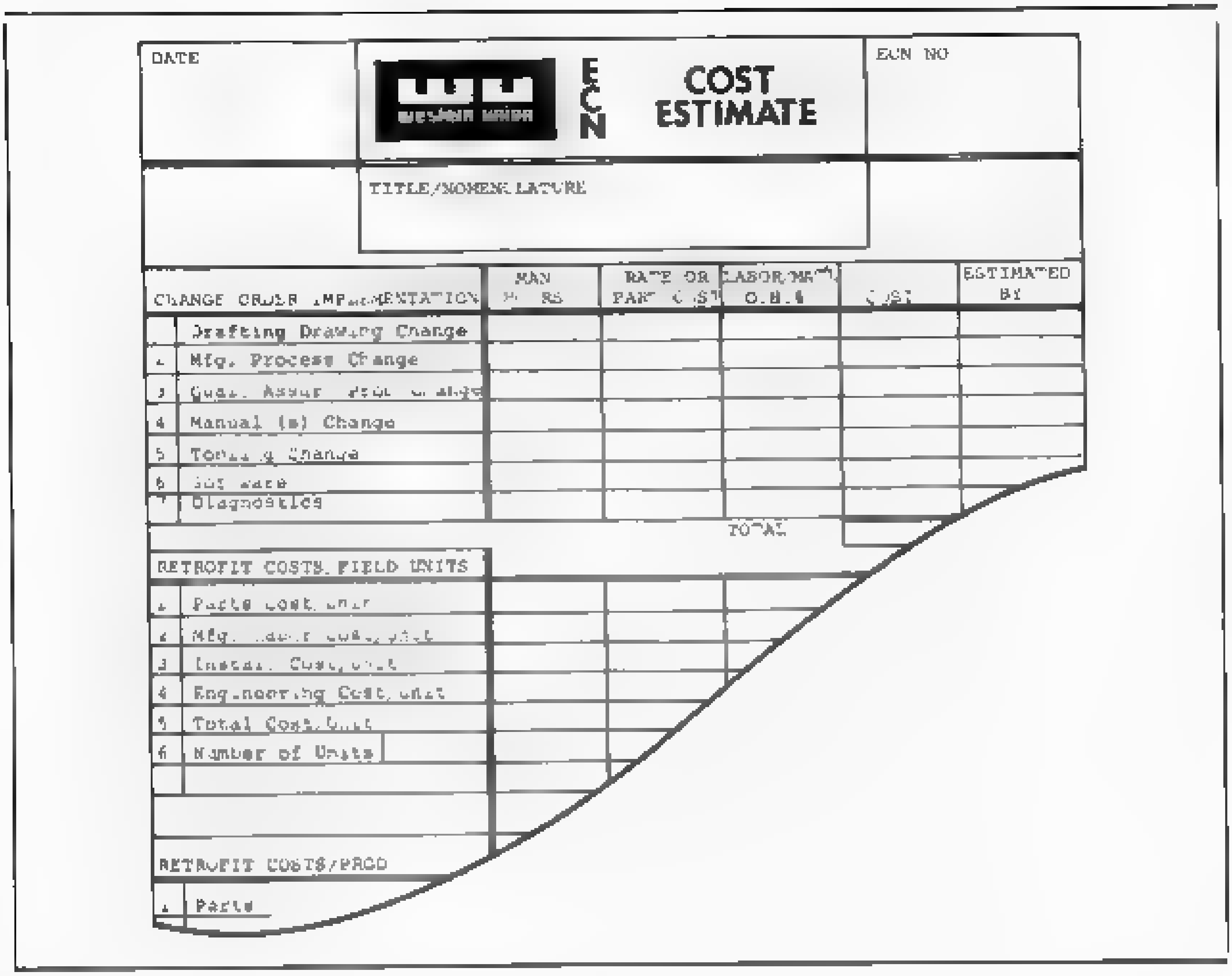
Figure 2 — Typical Configuration Identification for Colmux

1. DATE 2 ORIGINATOR	western union — ENGINEERING CHANGE ☐ RELEASE ☐ NOTICE	3 NUMBER PAGE ___ OF
15 CONCURRENCE ENGR. ______ MCC ______ PURCH ______ OPER. ______ INSTALL. ______ PL. EXT. ______ MAINT. ______ MKTG. ______ COMPTR. ______ PR. MGT. ______	4. TITLE/NOMENCLATURE 6. CHANGE COMM YES ☐ NO ☐ 7. TYPE I ☐ II ☐ 8. PROJECT/SYSTEM 10. CLASS OF CHANGE A☐ B☐ C☐ D☐ 11. PRIORITY URG. ☐ ROUT. ☐ DESIR. ☐ 12. EFFECTIVITY 13 ECR INCORPORATED	5 DWG.(S) NO. 9. NEXT HIGHER ASSEM. 14. TD ☐ PERM ☐
16. REASON FOR CHANGE		
17. DESCRIPTION OF CHANGE		18. STOCK DISPOSITION
19. ENGINEERING AUTHOR. DATE	20. TECHNICAL FACILITIES AUTHOR. DATE	

Figure 3 — Typical Form for an Engineering Change Notice

Procedure for Obtaining an Engineering Change Notice

The procedure for obtaining an Engineering Change Notice places a requirement upon the engineering department to consider a modification to a system or equipment. In addition, it develops a means for the submission of the proposed change to several functional departments in Western Union, who may be concerned. An Engineering Change Request which initiates this procedure, is identical with the Engineering Change Notice, except it is numbered and distributed across the company. Separate requests will be submitted for each unrelated design, however it is possible to include a number of Change Requests from various departments, on one Engineering Change Notice. A complete Engineering Change Notice describing the change is supported by revised drawings and



DATE	ECN COST ESTIMATE	ECN NO
	TITLE/NOMENCLATURE	

CHANGE ORDER IMPLEMENTATION	MAN HOURS	RATE OR PART COST	LABOR/MAT'L O.H.$	COST	ESTIMATED BY
1 Drafting Drawing Change					
2 Mfg. Process Change					
3 Qual. Assur. Proc. Change					
4 Manual (s) Change					
5 Tooling Change					
6 Software					
7 Diagnostics					
			TOTAL		

RETROFIT COSTS, FIELD UNITS			
1 Parts Cost/Unit			
2 Mfg. Labor Cost/Unit			
3 Instal. Cost/Unit			
4 Engineering Cost/Unit			
5 Total Cost/Unit			
6 Number of Units			

RETROFIT COSTS/PROD
1 Parts

Figure 4 — Typical Cost Estimate

other data to justify the Notice. One piece of this supporting data is the Cost Estimate shown in Figure 4. This is an integral part of the ECN and is completed by the cognizant engineer

The information to be entered on the Engineering Change Notice consists of the following

A. Block 5 contains the top assembly or drawing number of the item affected by the change

B. Block 7 contains the type of change which is dependent upon whether the baseline is affected or not The two types are: Type I change relate to design, reliability, maintenance, compatability, procurement, operational program, retrofits, part substitution or replacement, and spare parts requirements. Type II changes do not affect baselines, for example, they may specify the use of an equivalent semiconductor or alter the length of a machine screw

C. The class of change is determined by the category If a design does not meet the performance requirements, a Class A change is required If the change is required to meet operation other than the original usage, then a Class B change is designated. If the change affects procurement without affecting the original performance and is based on a cost savings, then Class C is designated

Changes which result in increased performance maintainability, and reliability without degrading or negatively affecting the performance requirements, are designated as Class D. One of these four (4) classes is entered in Block 10

D The priorities of change are entered in Block 11, they are either Urgent, Routine or Desirable. Changes necessary to maintain service, or customer schedules and those necessary to correct safety conditions are designated as Urgent. Routine changes are those which are required but do not affect revenue. A Desirable change, is a change which would not be detrimental if not installed immediately, but would enhance system operation or improve appearance.

E A Temporary Deviation is possible, for example, a component substitution by the Materials Management Department. It may authorize the release of a part from stock, that is not specified. This deviation may also expedite an ECN but will require a permanent ECN after a six month period. No more than three Temporary Deviations are allowed on an item before an ECN is mandatory.

Whenever the engineer is satisfied that he has complete information on the ECN, he makes a formal request to the Reproduction group in the Engineering Department, for a "red line" print (a "red line" is a blue print which reproduces with a red background.) for review of the change, which contains all of the associated documents and the formally prepared ECN. The reproduction group limits the distribution of the "red line" to members of the Change Committee. These should be reviewed by each committee member from the viewpoint of his own department. His requirements are proposed through the committee and concurrence may be shown in the block provided in the ECN. The "red line" is released by the approving signatures. The "Notice" is then reproduced and distributed as a complete package.

Configuration Accounting

Configuration Accounting is the reporting and documenting of changes made to Western Union systems and equipment. This effort in identifying the significant changes to a unit or assembly which affect "form, fit, or function," is done subsequent to the establishment of a configuration. Generally, it consists of a list of basic assemblies, units and subassemblies cross-referenced to the serialized equipment and the authorized changes. This accounting is maintained, for not only operational systems and equipment, but for associated spares with the supporting technical data. Column I is presently configured according to the Configuration Check List in Figure 2.

This list is basically a record of the Engineering Change Notices that have been made to a particular model of the equipment. The significant or major assemblies and sub-assemblies are listed in the left-hand column, so that the changes related to these items may be shown in adjacent columns. These constituent assemblies have their own List of Materials and are composed of such unique items as, line buffers, memory, back plane wiring or chassis and power supplies.

In Row 5, the type designation shows when a change in interface or performance has been made. The 2-digit number is changed according to a Class B, C, or D category in the ECN procedure.

Row 6, which is Effectivity, is the point at which the change is to be accomplished — and is shown by the serial numbers of the equipments affected.

The numbers under Type Designation and Effectivity are the ECN numbers associated with the assemblies to be changed. In this manner all modifications to changes in configuration of a specific equipment model are recorded and made available to Management.

In summary, Configuration Management is a management tool which assists in making decisions relative to the continued development and use of our plant. In addition, the procedures outlined in this article and established in the Quality Assurance Manual, provide the mechanics whereby people of differing skills can use the information readily. The goal of these procedures is to extract the necessary data so that they may be summarized in one document for management decision. The manual entries to this system, as outlined in this article, will eventually be computerized as this program develops. As part of the overall Quality Assurance program, the configuration management program and the detailed exhibits support the decision making process for the Quality Assurance Program at Western Union. ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■

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Management Reviews Help Keep Pace with Western Union's Expanded Services

Michael V. Montemurno

This article describes some new management tools introduced into Western Union to keep pace with its growth and the expansion of its services. A general look at the management tool, Review Boards, is made leading to the formation of Western Union's Corrective Action Committee. Because of the complexity of new systems, the Company has placed added emphasis on Quality Assurance, and has instituted the Quality Review Program which integrates management reviews.

Introduction

With the advent of the industrial revolution, the world has seen a remarkable growth in the size and complexity of organizations. The small shops of a century ago have evolved into the giant, billion dollar corporations of today. As a consequence of this revolutionary change there has been a tremendous increase in the division of labor and segmentation of management responsibilities in these organizations. The component groups that have developed as a result of this rapid change tend to grow into relatively autonomous groups each having its own goals and set of values. These groups sometimes lose sight of how their objectives and activities mesh with those of the overall organization.

Western Union has been involved in this expansion. The systems and services that our company offers today are much more complex than those of an earlier era. With the expansion of the Company and the increase in specialization, new problems have evolved. The interpersonal relationship which had been the cornerstone of quality service, has become difficult to maintain. The burden of coordination is constantly being directed to the executive level of the organization. As a result, it has become necessary to create staff functions responsible to these executives for some of the coordination, collection of basic data, sifting of data and presenting it in a form conducive to responsible decision.

One such staff function in many organizations is performed by Review Boards.

History

During World War II, the government developed Material Review Boards to pass judgment on deviant hardware. As we passed into the era of ICBMs, the Design Review Board concept was developed. The Design Review Board provides for effective control of "reliability" and "quality assurance" during and through the design and development stages of the program. In addition, it provides a means to formally verify and sign-off on the technical suitability of this design to the customer requirements.

Today, many of the major corporations are now using another assurative technique: The Change Control Board and Failure Review Board. The Change Control Board regulates and controls all change orders to effect efficient technical, economic and service improvements. The Failure Review Board provides formal evaluation and recurrence control of equipment failures. The need for these additional boards stems primarily from the high price of large systems and the one-of-a-kind nature of such products as missiles and space satellites. Yet any good management practice may be adapted to all types of products whether they be hard goods or services.

Western Union has recently added to its management procedures a Management Review Program. This program performs certain coordination functions that are necessary to implement an effective Quality Assurance Program.

Management Review

The additional procedures provide for the integration of management reviews for each of the following: the design, implementation and corrective action of equipment, systems and services. This integration of reviews is necessary so that periodic crisp presentations can be given to the executive level for decision.

To describe more fully the management review program, consider Figure 1, the General Case — Equipment or System — Service Life Cycle. The normal line functions start with the conception of an idea (conceive) and end with the salvage of the equipment. These functions are required whether it involves the entry of a new equipment, the implementation of a system or the start of a new service.

At appropriate times in the life of a system or equipment or at the completion of a significant phase of the life cycle, one of three types of reviews is held. These are Design Review, Implementation Review and Corrective Action Committee Review. The purpose of these reviews is to inform management of the progress of the projects and to assure management the necessary coordination has been accomplished and concurrence of all necessary groups has been obtained before proceeding to the next step.

The appropriate times for the reviews within the life cycle are shown in Figure 1. As indicated, there are six major reviews, two for each sub-committee, during the life of each project. It is reasonable to expect that in the larger or more critical programs there will be additional reviews to keep management informed of the correct accomplishment of significant milestones.

The integration of these several review boards or committees is shown in Figure 2. The Quality Review Committee with an established Level A charter reviews the activities of each of the following Level B committees.

Design Review
Implementation Review
Corrective Action Committee Review

Agreements and recommendations of the Level B Committees are presented to the Assistant Vice Presidents promptly. Recommendations are supplemented with full documentation of the staff work accomplished, so that a decision can be based on all the information available. In addition, the Level B Committee meetings present a forum of opinion so that line management may efficiently make appropriate decisions.

The Quality Review Committee is composed of permanent representatives from the Planning & Engineering Operation, Technical Facilities and Material Management Departments. Members of other line organizations are invited when the matter under discussion affects their interests.

The level of representation on the Level A meetings is Assistant Vice President with staff support by Directors. Meetings are conducted in a crisp manner so that the order of business is completed within two hours. The coordination of the material to be presented to the Level A Committee is the responsibility of the Quality Assurance group, represented by the Management Review Specialist. He, in cooperation with the various technical sections and the Quality Assurance representatives in each of the Level B groups, assembles the infor-

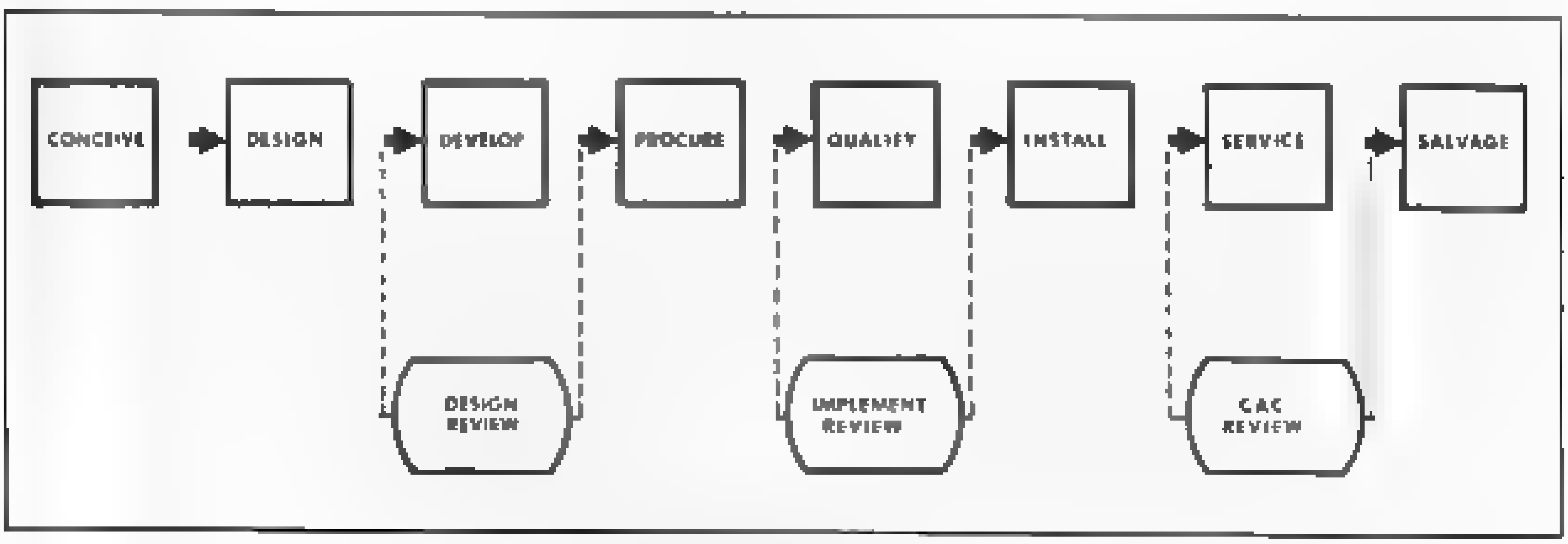

Figure 1—Life Cycle of a System or Service

mation and prepares the agenda for each Level A meeting. Because the projects reviewed are generally large and complex, proper support documentation must be available. Detailed minutes are recorded during each Quality Review Committee meeting. The minutes listing action items, agreements, recommendations and decisions are published and distributed to Committee members and designated individuals throughout Western Union.

Design Review Team

As shown in Figure 1, a Design Review meeting must be held at the completion of the design phase and again at the end of the development phase before the design is ready for release. The Design Reviews are not scheduled regularly, but are called periodically by the design Director, in accordance with the work schedule for each project. As each project is planned, a review team or sub-committee is appointed by management to represent them. The team representation of the Design Review Committee is indicated in Figure 2. A member of the Quality Assurance group is on each team to record the meetings. The Design Engineer is responsible for preparation of the agenda.

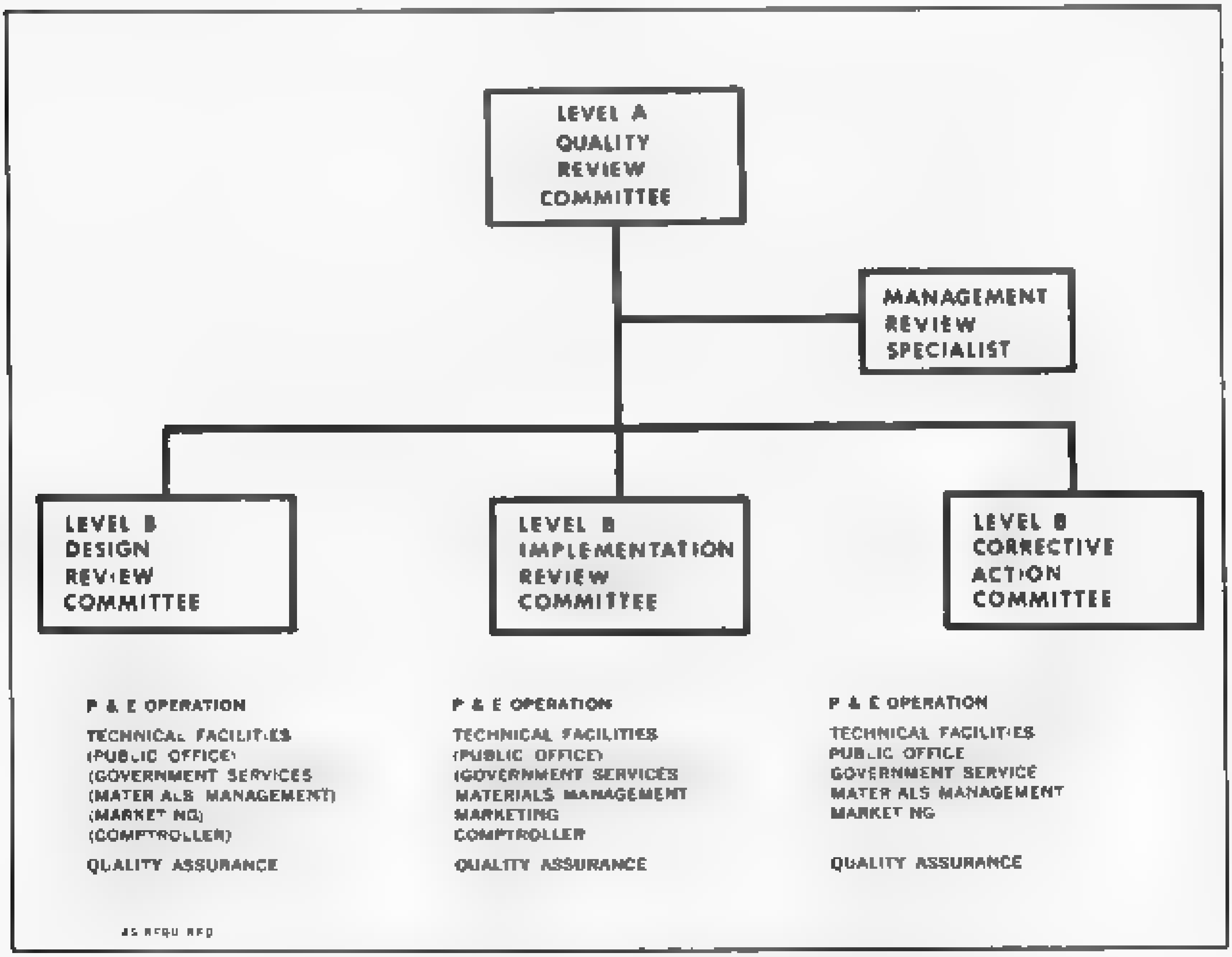

Figure 2—Interrelation of Level A Committee (Quality Review) with Design Review, Implementation Review and Corrective Action Committee (Level B)

The basic functions of the Design Review are as follows

1. Review the progress of the design/development activity
2. Assure that the design objectives include
   a) performance
   b) reliability
   c) operating parameters
   d) maintenance features
   e) interface requirements
   f) cost limits
3. Establish a brief for each design case and see that it is ready for presentation
4. Recommend various classes of design freezes as stated in the Western Union Quality Assurance Manual.
5. Prepare reports for the Quality Review Committee on the progress of the design.
6. Recommend to the responsible section and report to the Quality Review Committee
   a) Termination of the design effort, when warranted
   b) reduction of effort
   c) increased design effort
   d) the approval of a completed design project

Implementation Review

The second Level B Review Board is the Implementation Review Committee. This Committee differs from the Design Review Committee in its representation and in its functions. With regard to the format of the review, that is, calling a meeting, participation, preparation of the agenda and the recordings, the two committees are essentially the same

The functions of the Implementation Review Committee are

1. Establish an implementation case upon completion of design and establishment of requirements
2. With appropriate inputs from Marketing, establish the priority of implementation of the class of equipment
3. With inputs from Engineering, Technical Facilities and Marketing, recommend at which station the new equipment will first be installed
4. Follow the preparation of procurement specifications to assure that the equipment being specified can be obtained in the best interest of the Company
5. Integrate the production of test requirements.
6. Review the qualifications of all equipment manufactured for Western Union to be placed in service by Western Union.
7. Coordinate the configuration control activity for equipment added to the plant
8. Follow the progress of all implementation activity
9. Recommend the completion of an implementation case

The project program manager for the implementation calls meetings of the Implementation Review Committee in accordance with the schedule for each project

Corrective Action Committee Review

The third Level B review is the Corrective Action Committee Review. The activities and functions of this Committee are involved with problems encountered in the routine service period

In late 1966, the Corrective Action Committee (C.A.C.) was established to act as a bridge between Engineering and Technical Facilities to provide formal identification, technical evaluation and control of certain specific problems related to the maintenance and installation of equipment, system and equipment performance and the operation of the Western Union plant. This Committee reviews the recommendations to correct current problems and directs implementation of solutions to prevent similar problems in the future. In principle, the Corrective Action Committee is not new. The participants in a C.A.C. meeting have always been interested in corrective action in varying degrees. What is new is that a procedure is followed and — perhaps more important — record keeping and field reporting on the implementation and subsequent improvements are detailed

An important rule observed by this Committee is that "problems are not really solved at C.A.C. meetings"; rather, courses and direction for corrective action and preventive measures are generated or selected. The meetings are geared to corrective action review, not to recriminations or fault finding.

Since its inception, the C.A.C. has expanded the scope and detail of its effort. The Committee presently functions with two levels of meetings. The Level B meetings held each week are attended by Directors and Managers from appropriate sections of Engineering and Technical Facilities. The first meeting of each month is devoted to consideration of problems in the area of Transmission. The second meeting is concerned with the area of Switching and the third meeting with Terminal Equipment problems. The fourth meeting, which is a Level A meeting, is a review meeting attended by Assistant Vice Presidents and Directors. At the Level A meeting the recommendations generated at each of the Level B meetings are presented and the action taken by the responsible section is reviewed.

All of the meetings are conducted in keeping with a varied agenda. They vary according to the problems on hand, priority, availability of representatives, related data, etc.; but the two basic rules for the conduct of meetings are adhered to, that is, they are short and concentrate on the business at hand.

On occasion, it has been necessary to deviate from the meeting schedule to concentrate on some critical problem. When this occurs, the affected committee members or their alternates are notified by telephone and either a special meeting is called or the agenda for the scheduled meeting is altered.

The Committee has considered problems in many of Western Union's systems and services. The active areas in which the Committee is involved are as follows:

- MICROWAVE BEAM
  - — FREQUENCY DIVISION MULTIPLEX EQUIPMENT
  - — FREQUENCY DIVERSITY RADIO EQUIPMENT
- BACKUP POWER PLANTS FOR MICROWAVE SYSTEM
- BROADBAND SWITCHING SYSTEM
- HOT LINE SYSTEM
- TELEX SYSTEM
- TERMINAL EQUIPMENT
  - — TELEPRINTERS
  - — FACSIMILE
  - — PAPER TAPE TRANSMITTERS
- WAY CIRCUIT SYSTEMS
  - — SELECTORS
  - — CONTROL STATIONS
- DATA TRANSMISSION EQUIPMENT
  - — DATA MODEMS
  - — EQUALIZERS
  - — DALCODES

The following are examples of corrective action programs which have been or are being implemented to resolve critical problems which were affecting service.

1. *Microwave System — Emergency Back Up Power Plants*

   Complete beam losses because of dual emergency power plant failures. The Committee assigned a field investigation team to visit sites in all divisions and investigate power unit failures. The steps taken are summarized in these categories.

   A. Improved reliability through changes to the equipment.

   B. Increase reliability through improved maintenance procedures, schedules, training and supervision.

   C. Increase system availability by reducing power unit down time.

2. *Circuit Continuity Failures Through Multiplex Equipment*

   Loss of current continuity through cables, connections and contacts.

   A. Inspection/Replacement Program of all gold leaf contacts throughout the system.

   B. Replacement of Sub Minax cable assemblies.

3. *Traffic Level Variation*

   Variation of traffic levels through the transmission facilities.

   A. Replacement of potentiometers in Group and Supergroup Interconnect Amplifiers.

   B. Replacement of potentiometers in the multiplex carrier supplies.

   C. Replacement of temperature sensitive transistors in the transmission path equipment.

4. *Impulse Noise*

   Impulse noise due to various switching transients causing circuit interruptions.

   A. Installation of limiting varistors on Radio Beam Order Wire Dial Station Selectors.

B Installation of limiting varistors on all Radio Beam Voice Channels.

C Limiters installed on Hot Line trunks, resulting in suppression of all switching transients originating in the Hot Line equipment

D Installation of battery filters in the Broadband Switching Exchanges.

5 *Tie Line Facsimile Service*

Field investigation and identification of problems associated with Desk Fax equipments.

A. Modification of Desk Fax units to improve reliability of key components.

B Elimination of repeated equipment failures resulting in reduced down time

C Conversion and overhaul of Tie Line Concentrator Recorders with superior components

As indicated earlier, a fundamental principle of the formal committee procedure is record-keeping and field reporting. To provide the status of corrective action efforts on a continuing basis, two forms were developed They are: the Engineering Case Reports and the System Task Status Report.

1) Engineering Case Report

The Engineering Case Report provides the state of the engineering effort for each problem. Specifically, the Case Report contains the following information

- Task Serial and Priority Number
- Assigned Section and Subsection
- Start data, pertinent Work Order information
- Description of Task and Projected Results
- Work accomplished, In Process and remaining
- Percent Status of the Engineering Evaluation and Action Phase of the Task.

On a monthly basis, the responsible Engineering sections are requested to update the Case Reports.

2) System Task Status Report

The System Task Status Report provides the state of the engineering evaluation, action, and the state of Technical Facilities procurement, instruction and installation. The System Task Status Report is updated monthly to reflect the latest Engineering and Technical Facilities progress, and presented at the Corrective Action Committee Review meeting.

As mentioned previously, the activities and functions of the Corrective Action Committee are related to problems encountered in the routine service period

There is another situation that requires calling a meeting of the Corrective Action Committee Upon completion of installation and pre-operational tests, the problems encountered during the tests and during the initial service period are presented to the Corrective Action Committee. At these meetings decisions are made to change the operational and maintenance procedures, submit the problem areas for redesign, or to accept the difficulty as characteristic. Thus, when the project is completed and the installed complex is turned to routine service, solutions to all of the identified problems will have been determined

As the Corrective Action Committee has steadily identified problems, provided technical evaluation of solution to these problems and directed the implementation of the solution, subsequent improvements in the performance and operation of the Western Union plant have been realized

Increased Efficiency

The Management Reviews have been found to increase the efficiency of and supplement the existing management review activities. It is expected that in the areas of design, implementation and technical corrective action, these meetings will help to provide Western Union with a coordinated program for presenting and recording the status and quality of the many programs, equipment, systems and services. Another factor which has made the Corrective Action Committee's activities successful is the dissemination of committee meeting minutes and status reports to the field divisions. This has closed the information feedback loop resulting in better cooperation and coordination between headquarters and the divisions. These reviews assist management to assess the probabilities of success and the risks involved in any venture ■ ■

Reliability Projection and Analysis

Fred M. Fink

Service requirements for present Western Union Communication systems stress high standards of accuracy and operational continuity over long time intervals. Future service requirements will be even more stringent. The fulfillment of these performance requirements in an economical manner is facilitated through an increased emphasis on the aspects of design, installation and utilization which yield a high system reliability. For maximum effectiveness, reliability concepts must be continuously emphasized and applied throughout the design, development, and operational-maintenance periods of a system's lifetime. The individuals involved with the various stages of system development and operation are therefore required to be knowledgeable in the particular concepts and techniques of reliability engineering and analysis. The purpose of this article is to illustrate and explain those basic concepts of reliability that are directly involved in the reliability activities of such functional groups as system design engineering, the manufacture or vendor monitoring facility, the installation-test-maintenance organizations, and the customer or system user.

Reliability and Performance

The ultimate criteria of a Western Union system or equipment has always been its overall capability to perform an intended function. In past years this performance capability, defined throughout industry in terms of effectiveness, was expressed qualitatively as poor, acceptable, good, or excellent. Thus, if a system or equipment was not effectively performing its intended function, as indicated by the subjective terms of measure, corrective action was taken to isolate and correct the deficient system or equipment attribute contributing to the loss of effectiveness.

Reliability is one important aspect of performance that has a direct influence on effectiveness. It has been developed into a measurable and quantifiable parameter of system performance. Since 1950, the research and development associated with reliability has been pursued basically from two points of view. The first has centered on data collection and failure mode analysis for the purpose of accumulating and updating values of failure rate for components of equipment and systems. The second has been concerned with the development of analytic methods to define and describe reliability concepts in the necessary quantitative form. Recently, a third area has developed which seeks to define and illustrate the application and integration of reliability concepts within overall company operations and decision making activities.

The impetus for the rapid development of reliability concepts, since the end of World War II, has been the increasing complexity of military weapons and electronic systems and their operating performance requirements. The communications industry as a whole, and Western Union in particular, has experienced this rapid growth in system complexity as a result of public, private industry and government demands for new and varied communication services.

In addition to reliability, various related concepts have been developed in quantified form to yield a more overall measure of effectiveness in system performance. To avoid any misinterpretation and misuse of these specifically defined concepts, definitions of these terms are required.

The following glossary of reliability terms contains with each definition, an example of the application of the term with respect to a typical Western Union System Model illustrated in Figure 1.

GLOSSARY of RELIABILITY TERMS

Operating Time is the time during which the system sub-system or unit of equipment is operating in a manner satisfactory to a user

Example: The individual operating times for all portions of the sub-system blocks, in the Western Union model system, as required for meeting a specified communications requirement

Active Repair Time is the time during which one or more technicians are working on a failed system or sub system to effect its repair

Example: The accumulation of on-site, maintenance technician time in repairing a failure to any portion of a sub-system block in the model Western Union communications system

Logistic Time is that time for which repair of a failed system or sub-system is delayed because of the immediate unavailability of a replacement part or module

Example: Delay in effecting repair on a subscriber's terminal (sub system block #1) as a result of the immediate unavailability of the required replacement part either on the subscriber's premises or in the maintainer's possession

Administrative Time is that portion of time which covers such activities, associated with failure incidents as maintenance travel time, delays in trouble or failure notification and maintenance dispatcher delay (delay associated with a buildup of a waiting line of trouble calls)

Example: The dispatching of a Western Union technician from one subscriber location to another to effect repair of a failed terminal device Administrative time in this case would involve dispatcher delay (maintainer must first complete present repair activity) and travel time from one subscriber's location to the other's location.

Down Time is the total time in which a system, sub-system, or unit of equipment is not in an acceptable operating condition. Down time consists of the total of active repair time, logistic time and administrative time

Example: The total elapsed time from the point in time at which failure is detected in any of the sub-system blocks to the point in time at which repair and return to operational status has been accomplished.

Free Time is the time during which operational use of the system, sub-system, or unit of equipment is not required

Example: The equivalent 2 days time (Saturday and Sunday) of those portions of the sub-system blocks utilized by a subscriber whose service requirements exist for only the 5 working days of a week

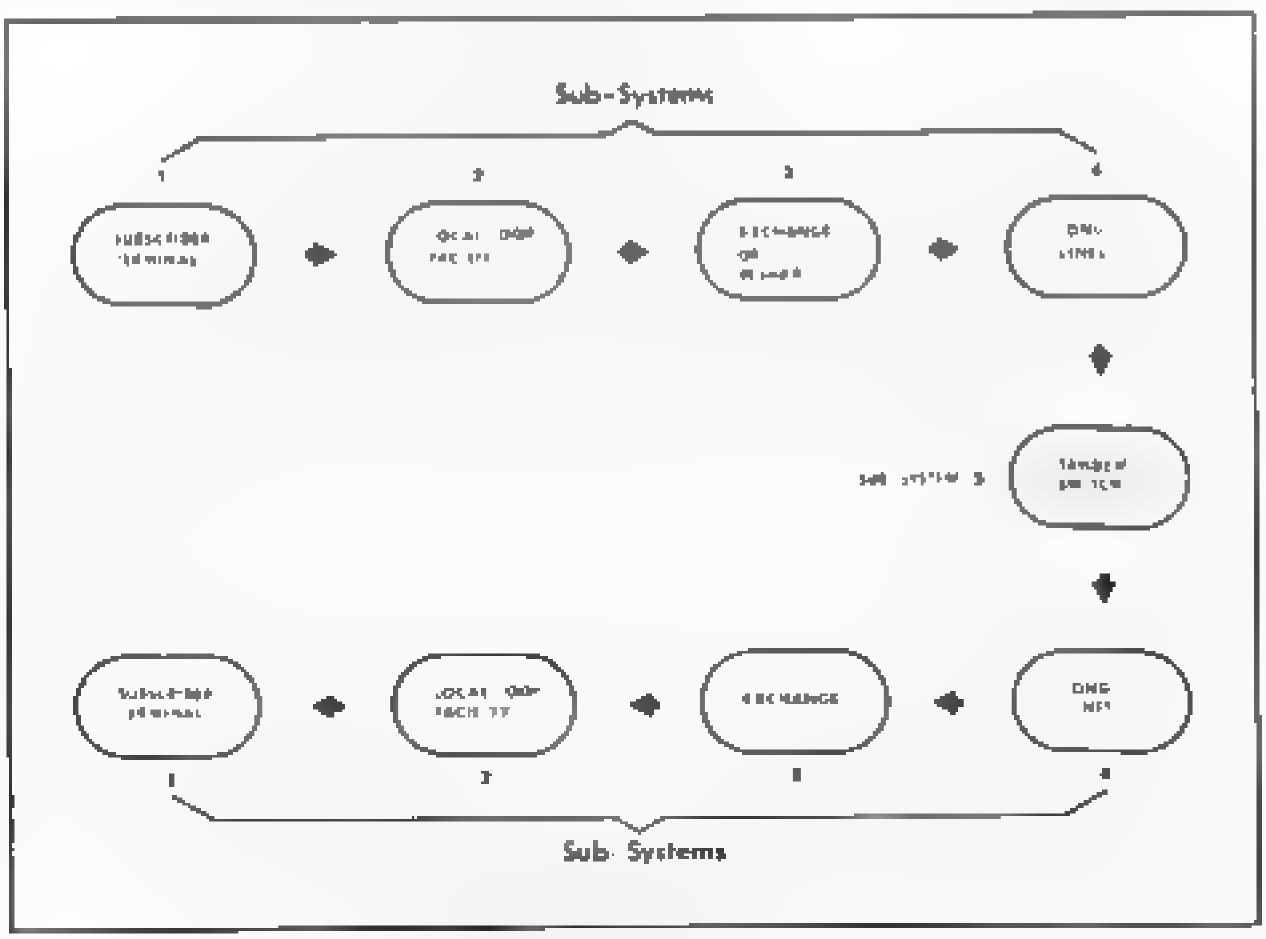

Figure 1—A Typical Western Union System

Stand-by Time is the time during which the system, sub-system, or unit of equipment is presumed to be in operable condition, but is awaiting the arrival of a service requirement, or is being held for emergency use.

Example: Time intervals within the period of required operational status for a specified subscriber terminal where the subscriber does not place service requirements on the system.

Repairability is the probability that a failed system, sub-system, or equipment will be returned to an operable condition within a specified active repair time interval. For Western Union, the specified period of active repair time is set as one hour, to yield a numerical value of repairability.

Example: The probability a failed unit of equipment at any sub-system block will be repaired within 1 hour after technician arrival and commencement of work (assuming 100% spares are immediately available).

Maintainability is the probability that a failed system, sub-system, or unit of equipment will be restored to an operable condition within a specified total down time interval. For Western Union, the specified period of down time is set at one hour to yield a numerical value of maintainability.

Example: The probability a failed unit of equipment at any sub-system block will be repaired within 1 hour immediately following initial detection or discovery of the failure.

Reliability is the probability that the system, sub-system, or unit of equipment will operate in a satisfactory manner for at least a specified period of operating time. For Western Union the specified period is set as one hour to yield a numerical value for reliability.

Example: The probability a unit of equipment at any sub-system block will remain in operational status for 1 hour of operating time in which service requirements are being satisfied.

Intrinsic Availability is the probability that a system, sub-system or unit of equipment is operating satisfactorily at any point of time which is the composite of operating time and active repair time.

Example: If we assume that average or mean values of active repair time intervals and operating time intervals between failure occurrences (MTTR and MTBF) exist for a certain unit of equipment within any sub-system block, then the intrinsic availability for this equipment may be expressed simply as:

$$\text{the ratio } \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$

Availability is the probability that a system, sub-system, or unit of equipment is operating satisfactorily at any point of time which is the composite of operating time and down time.

Example: If we assume that average or mean values of down time intervals and operating time intervals between failure occurrences (MDT and MTBF) exist for a certain unit of equipment within any sub-system block, then the availability for this equipment may be expressed simply as

$$\text{the ratio } \frac{\text{MTBF}}{\text{MTBF} + \text{MDT}}$$

Operational Readiness is the probability that a system, sub-system, or unit of equipment is either operating or is ready to be placed in operation upon demand, at any point in total time which is the composite of operating time, free time, stand-by time, and down time.

Example: Assume that average or mean values of down time intervals and of calendar time (composite of operating, free and stand-by time) intervals between failure occurrences exist for a certain unit of equipment within a sub-system block. Denote these average values as MDT and MCT respectively. Then operational readiness for this equipment is simply

$$\text{the ratio } \frac{\text{MCT}}{\text{MCT} + \text{MDT}}$$

Effectiveness is the probability that a system, sub-system, or unit of equipment can successfully meet an operational requirement upon demand.

Example: Assume a subscriber's operational requirement averages out to a certain interval of time, t. Assume we are interested in the effectiveness of the subscriber's terminal equipment of sub-system block #1 in meeting his operational requirement over the time period, t. This effectiveness consists of the joint probability expression of terminal equipment operational readiness and terminal equipment reliability over the operating time, t. Stated another way, the sub-system block #1 effectiveness is the probability that the sub-system is in an operational state at instant of service demand by the subscriber multiplied by the probability of sub-system operational success over the operating time interval, t.

The relationship of these various concepts within the overall performance measure of effectiveness is then illustrated in Figure 2.

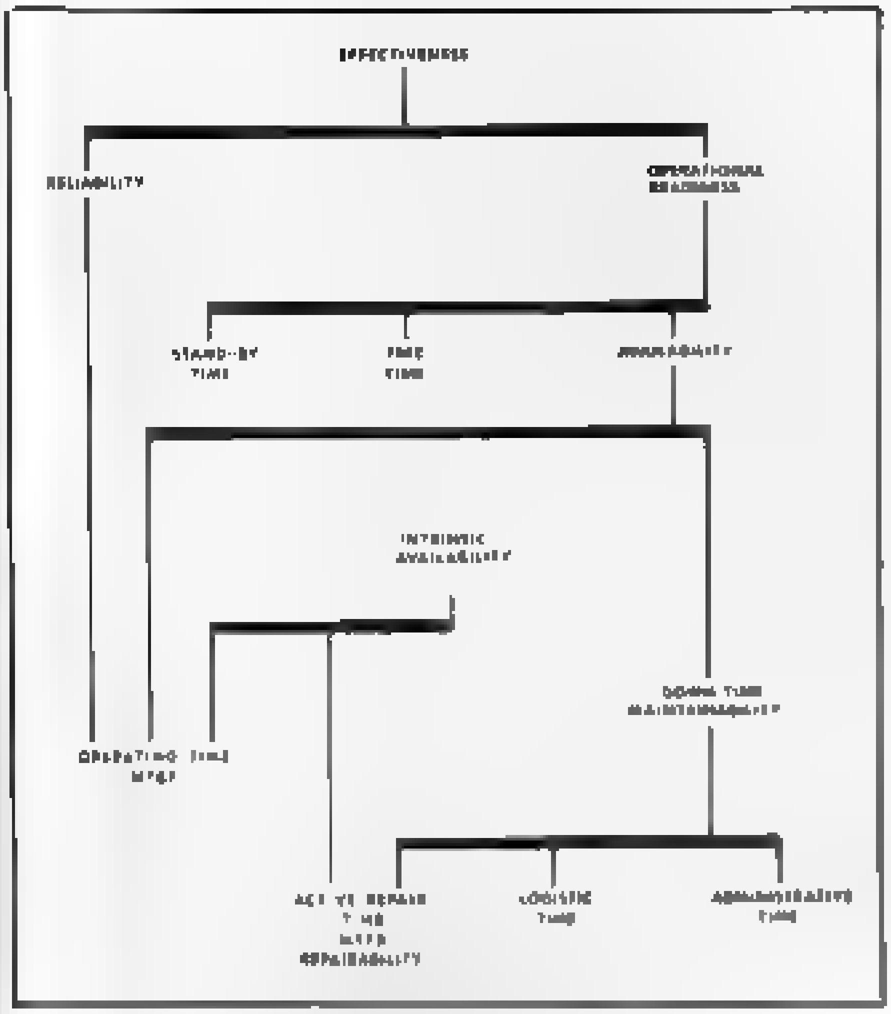

Figure 2—Relationship of Reliability Terms to Overall Effectiveness

Mathematical Development

The list of defined terms on the previous pages clearly indicates that the mathematical basis for the analysis of performance and reliability consists of well defined probability and statistical concepts. Reliability studies are dependent upon such factors as random variables, probability density functions, cumulative distribution functions, and reliability distribution functions. The application of these concepts to reliability analysis is illustrated in the brief mathematical development provided in the Appendix of this article, which appears on page 40.

Before discussing specific mathematical functions that are applicable to the reliability analysis of Western Union equipment and systems, the important concept of failure rate should be explained. In speaking of system or sub-system failure rate, we simply mean the rate at which failures occur over an arbitrary sub-interval of the operational life cycle of a system or sub-system. Reliability literature usually refers to failure rate as λ^{3-4}. In our application at Western Union, failure rate is expressed as units of failures/hour. For practically all Western Union electronic and electromechanical equipment the failure rate is expected to follow a rather universal trend in which it assumes clearly defined functional forms over the three periods of the operational life cycle. Figure 3 shows that λ, in turn becomes a decreasing function of t, a constant over a range of t, and an increasing function of t.

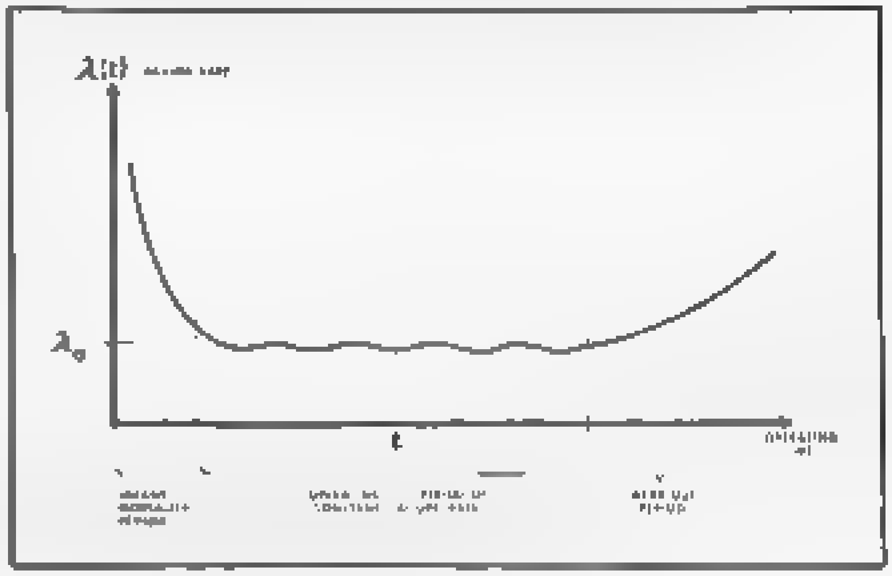

Figure 3—Plot of Failure Rate vs Life Cycle

The failure rate pattern within each of the three periods of an equipment's operating lifetime induces a unique probability density function which describes the distribution of operating time values between failures within each period. Figure 4 illustrates the usual shape of the curve for the general mathematical expression of the probability density functions, $f_i(t)$ where $i = 1, 2, \& 3$ corresponding to each of the three periods.

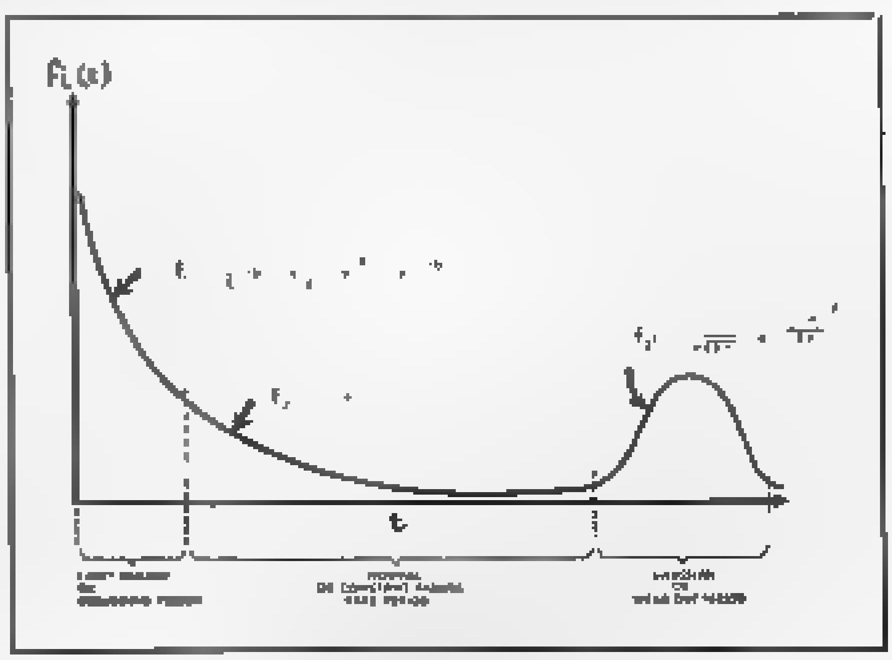

Figure 4—Plot of Probability Density Function vs Life Cycle

Debugging Period

Period 1 is known by a variety of names such as early failure, infant mortality, or debugging period. In this period, high failure rate parts are uncovered and defects that escaped quality control activities are corrected. The number of failures and hence the failure rate decreases rapidly in this period. The general mathematical expression used to approximate $f_1(t)$ is called the Gamma distribution. In using this function to describe the distribution of failures, the parameter, a is less than 1 and is simply the inverse of the number of failures occurring over the time duration of the infant mortality period. The parameter b, corresponds to the arithmetic mean of the operating time values between failures of this period.

Experience obtained during installation and early operational phases of Western Union's Dalcode systems appears to verify the existence of this initially high but rapidly decreasing failure rate for these electronic devices. A few instances of IC (Integrated Circuit) logic card failures within a year of system installation are indicative of defective ICs which escape the vendor's quality control process on the chance probability (Consumers Risk) associated with lot sample inspections. Other early Dalcode failures or operational cutover delays have resulted from vendor associated wiring errors.

Constant Failure Rate

Period 2 of a system's life cycle is known as the constant failure rate period. This is the period in which the reliability prediction and analysis of Western Union electronic systems is accomplished. The probability density function which describes the distribution of operating times between failures occurring in this period is the well known exponential failure distribution. The lone parameter of this function is simply λ, the predicted or demonstrated constant failure rate. A significant feature of this constant failure rate period is that the MTBF is simply the inverse of the failure rate, λ.

Wear-out Period

Period 3 is known as the Gaussian or wearout period in which critical sub-systems fail from wear and age. The well known Normal or Gaussian distribution function is the approximation used to describe the distribution of failures in time for this last period. The two parameters of this expression are the arithmetic mean of operating times between failures, μ = MTBF, and σ, the standard deviation of the population of operating time interval values. Normally, if such a period is known to be in existence within the useful life of the system, overhaul or replacement of the critical sub-systems is initiated prior to the anticipated occurrence of wear out failures.

Examples of Western Union equipment or sub-systems currently operating in their use or wearout periods are Type 20, 30 and 40 Carrier Telegraph equipment and Public Message System relay center equipment. Efforts to maintain and increase operational continuity (Reliability) on Western Union systems composed of these aging units of equipment and sub-systems involve concentrated maintenance attention and scheduled implementation of plant modernization plans.

Analysis Procedure

The reliability analysis of a complete electronic or electromechanical system begins with the definition and determination of the sub-systems or functional units. The system is then viewed as a structure of sub-systems or functional blocks (a reliability block diagram) which is constructed from definitions for principle modes of system operation and failure. Reliability analysis is then initiated on these sub-system blocks to obtain reliability functional expressions, failure rates, or MTBF values through the techniques of failure rate prediction and assignment or statistical analysis of performance and test data. An overall system reliability functional expression is then obtained by mathematically combining the individual sub-system block reliability expressions.

The activity of reliability projection estimates system, sub-system, and equipment reliability during the engineering phases of feasibility study, design and prototype development. This estimation is accomplished by following the step-by step procedure as detailed in the previous paragraph. The distinguishing feature of reliability prediction in the analysis procedures above is that sub-system block failure rates are computed from the derived and assigned failure rates of the constituent sub-system components. Initially, these assigned part and component failure rates may be obtained from published tables of several sources.* Examples are the failure rate and stress tables of MIL-HDBK 217A and the RADC Reliability Notebook. Within Western Union, failure rates obtained from previous

performance experience and test data also serve as a source for the selection and assignment of component failure rates.

Again the Dalcode is an example of reliability prediction as applied to a product of Western Union design and development. This technique of reliability prediction was performed on the Dalcode to provide an estimated measure of the reliability inherent to its basic design and operational concepts. Specific analytical tasks accomplished in this prediction effort were

1. Definition of Dalcode operational configuration — a single unit of the usual dual configuration per cabinet.

2. Definition and identification of sub-system blocks — groups of discrete components and ICs performing basic functions.

3. Formulation of definitions for prime and secondary modes of Dalcode failure

4. Construction of overall Dalcode reliability block diagram

5. Assignment of failure rates to components within each functional or sub-system block defined in (2) above

6. Calculation of failure rate for each subsystem block of the Dalcode reliability diagram.

7. Derivation of analytical reliability expression for each defined mode of failure

8. Calculation of MTBF values corresponding to reliability expressions of each failure mode

Accomplishment of these tasks resulted in a predicted MTBF of 7100 hrs. for a Dalcode failure mode defined as the simultaneous loss of all low-speed and high speed traffic in both send and receive directions

Prediction Accuracy

The accuracy of any reliability prediction is dependent on the amount of effort expended in the detailed analysis associated with the following tasks

1. Reliability block diagram development.

2. Component or sub-system failure rate assignment and calculation.

Ball Park Estimate

One reliability prediction technique which provides a first approximation of reliability is the "ball park" estimate. In this prediction effort, each component type is assigned a single average failure rate with no allowance for stress application factors. In addition, the overall system failure rate is simply computed as the sum of all component failure rates. As one can see, this prediction technique eliminates considerable analysis time required for failure rate assignment and reliability block diagram construction. The elimination of analysis time does, however, sacrifice accuracy and confidence in the final prediction result

Detailed Prediction

At the opposite extreme, a final detailed reliability prediction accomplished near the close of a system's design and development phase, does result in a more confident and accurate estimate of reliability. This detailed reliability prediction requires that extensive effort and time be expended in the areas of failure rate assignment and stress analysis as well as reliability block diagram construction.

In the accomplishment of a limited number of reliability predictions on Western Union equipment, a policy of flexibility was adhered to in the selection of prediction techniques. Predictions to date have usually been compromises between the extremes of the "detailed" and "ball park" procedures. The selection of a specific prediction method was generally made through consideration of time and information availability as well as end use of the prediction result. For example, the Dalcode reliability prediction required considerable analysis time in the development of the reliability block diagram to overcome certain assumptions made with regard to stress factors in the calculation of component failure rates. A degree of confidence in the results of the final prediction approaching that of a "detailed" prediction effort was desired since this prediction analysis was earmarked for inclusion in a Dalcode Design, Reliability, and Systems Application Report.[4]

In the use of reliability concepts by the design engineer, the prediction effort develops criteria for selecting courses of action that affect reliability

The primary purposes of reliability prediction can thus be identified as follows.

1) *Feasibility Evaluation:* The establishment of reliability feasibility through comparison of predesign predictions with desired system reliability requirements.

2) *Comparison of Alternate Configurations.* Selection of an optimum system configuration by trade-offs between reliability predictions and estimates of cost, weight, performance, etc.

3) *Allocation of Requirements:* Reliability requirements must be established for all equipment units that comprise a complete system. The requirements are determined in consideration of reliability required of the system, relative complexity of the subsystem units, and the relative importance of functions performed by the units.

4) *Identification of Reliability Problems:* The process and steps involved in system reliability prediction identify sources and causes of unreliability with respect to sub-system classes, operational modes, and severity of alternative failure possibilities.

5) *Maintenance and Logistics Planning:* Decisions as to what units should be made repairable during system operation must be based on predicted failure rates. Predictions are also used for making initial estimates of requirements for test equipment, maintenance personnel, spare parts, accessibility of parts, placement of test points, etc.

6) *Determination of Data Deficiencies:* The process of making reliability predictions focuses attention on items for which adequate data has not yet been obtained.

7) *Measurement of Progress.* Reliability predictions are the means whereby progress towards achievement of the reliability goal is measured.

8) *Demonstration of Compliance:* Reliability predictions are sometimes used as proof of compliance with a reliability requirement, when there exist problems of small test population and excessive test time.

Several activities associated with the manufacture of prototype and follow-on operational systems directly account for the degree to which reliability is built into the finished product. These activities of the production phase serve to assure that the reliability of system design becomes the reliability of system actuality. Some typical activities affecting the creation of reliability along with system manufacture and assembly are as follows

1) Preparation and control of documentation, drawings, and specifications to implement manufacture and assembly

2) Preparation and control of procurement specifications

3) Receiving parts and sub system inspection

4) Qualification testing.

5) Control and selection of vendors and subcontractors

6) In-process inspection and control

7) Reliability test verification on selected portions of the system or on selected samples of equipment

Reliability activities during the installation phase of a system are related to the specific tasks of getting the system in and operating. Frequently, a newly installed system goes through an infant mortality period of excessive failures as previously discussed and illustrated by Datacode experience. The important activity of this period is to track down the root cause of each failure occurrence. The identification and analysis of each failure in this period is of vital importance so that errors and omissions in system design, manufacture, testing, inspection, or installation might be corrected.

An additional important reliability activity at this time is to determine through statistical analysis of performance, operation, and failure data when a new system has passed from the infant mortality period into its normal, predicted reliability period. This is usually a period of relative constancy in system failure rate as illustrated by small random variations of the failure rate about a clearly defined average value.

Collection of Data and Analysis

The collection and analysis of the performance data for operating systems which have passed beyond their debugging period, constitutes a final concern of reliability activities. In this effort, the reliability activity of data collection and analysis of operating systems provides the following important services and information

1. A quantitative measure is obtained of how close an operating system or equipment comes in meeting designed reliability goals.
2. An identification of the causes of failures in systems and equipment. This provides for the assignment of these problems to the proper area of concern to effect the necessary product improvement through design change and modification action.
3. A determination of the effects by subsystems and inter-connecting links on total system performance.
4. An information source is developed for design personnel working on new and comparable systems and equipment. The collected data and analysis results represent achieved and demonstrated performance levels for similar system, equipment, and components subjected to actual field operation and environment
5. A realistic means for comparing actual operating system and sub-system reliability with earlier reliability prediction and laboratory demonstration testing. This provides a verification and measure of confidence in prediction methods, lab testing activities, and reliability demonstration testing techniques.
6. Analytical results enable accurate planning for maintenance workloads, spare parts stocking levels, and system operational procedures

The reliability analysis on performance data of Western Union equipment and systems is greatly facilitated through the EDITS field reporting system. This anticipated failure reporting system, as described in a following article, will eventually provide the basic statistical data and analysis software with which the reliability parameters of our operating systems can be continually monitored. In addition, all the performance measures contributing to the overall system effectiveness as described in the glossary and in Figure 1, can also be calculated and monitored. The joint attainment of EDITS enhancement and operational reliability-performance monitoring objectives will thus provide Western Union the extremely useful information and services listed above.

Conclusion

The preceeding study of reliability has been accomplished by investigation of its historical origin definitions, relationships to other performance measures, and mathematical foundations. Knowledge and understanding of these underlying aspects provides the capability for the application of reliability concepts throughout a system's life cycle.

The extensive communication-information systems currently being planned, designed, and implemented by Western Union require continued and increasing emphasis on reliability concepts and activities. These new systems, in a variety of hardware software configurations, will certainly impose challenges in the application of reliability within the periods of system design-development, manufacture, test, installation and operation maintenance. Successful implementation of several new complex systems indicates that Western Union personnel, associated with all the phases of system evolution, have met these challenges of system reliability

* * * *

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5. Western Union Engineering Memorandum 4581-A, "Dalcode 12324-B Design, Reliability, & Systems Application Report," Aug. 30, 1968.

APPENDIX

FOR

RELIABILITY PROJECTION AND ANALYSIS

(pages 32 thru 39)

This appendix serves to illustrate the mathematical and statistical principles which form the basis of reliability analysis. As will be shown, the mathematical development of the reliability formulae involve statistical distributions of operating time between failure incidents.

For reliability applications, the random variable, T, is defined as the set of all numerical values of time, t which can be assumed by the operating time intervals between successive system failures. T is a continuous random variable; the system operating time intervals, between failures, can theoretically assume any value, $t \geqq 0$. The continuous random variable, T, is, expressed in the following equation:

$$T = \{t \geqq 0\} \tag{1}$$

The probability density function for the continuous random variable, T, is defined in terms of the probability that T lies within an arbitrary interval, $[t_1 \text{ to } t_2]$ of the time scale, $t \geqq 0$. Thus, if the probability that a value of T falls within the arbitrary interval, $0 \leqq t_1 \leqq t \leqq t_2 < \infty$, is expressed as,

$$\int_{t_1}^{t_2} f(t)\,dt, \tag{2}$$

then $f(t)$ is defined as the probability density function for the continuous random variable, T.

The cumulative distribution function for the continuous random variable, T, is the probability that a value of T is $\leqq$ a certain value of time, t. This cumulative distribution function is expressed mathematically as,

$$F(t) = \int_0^t f(t^*)\,dt^* \tag{3}$$

where t* is the dummy variable of integration since the probability density function of the integrand and the integral limit are both functions of time, t. In reliability analysis, $F(t)$, is often referred to as the unreliability function since it yields the probability that a value of operating time between system failures is $\leqq$ a certain value of time, t.

The reliability distribution function $R(t)$ for the continuous random variable T, is mathematically related to the cumulative distribution function, $F(t)$ as its unity complement. Thus,

$$R(t) = 1 - F(t) = 1 - \int_0^t f(t^*)\,dt^* = \int_t^\infty f(t^*)\,dt^* \tag{4}$$

$R(t)$ is the probability that a value of system operating time between failures will be $\geqq$ a certain numerical value of time, t.

The well known system characteristic of MTBF can now be defined from its mathematical concept, as an arithmetic mean of operating time interval values. Thus, the mean of the continuous random variable, T [with] probability density function, $f(t)$, is given as

$$\int_0^\infty t \cdot f(t)\,dt. \tag{5}$$

Frequently, it is more convenient to use an alternative but equivalent expression to obtain the MTBF of the random variable, T with reliability distribution, $R(t)$. Thus, MTBF is also given as

$$\int_0^\infty R(t)\,dt.$$

* * * * * * * * *

Authors in This Issue

John L. Hart, III, Director of Communications System Engineering, provides consulting services, advanced development, and system integration engineering in the field of communication systems. Since 1968, Mr. Hart has led the team which has developed the management system documented in the recently distributed Quality Assurance Manual.

As Director of Quality Assurance and Specifications, Mr. Hart developed management systems for Western Union Quality Assurance, and coordinates or generates the specifications which govern the performance of the communication systems.

He is a member of USA Standards Institute Subcommittee X3.3 on Data Communications, EIA Technical Committee TR30 and the Armed Forces Communications and Electronics [redacted].

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Announcement

McConnell, R.: Quality Assurance Program
Western Union TECHNICAL REVIEW, Vol. 23, No. 1
pg. 2-3.

The first Quality Assurance Manual for the Communciations Industry has been written by a dedicated group of engineers who have studied the techniques of Quality Control at Western Union.

This manual is available only to Western Union engineers.

Quality Assurance
Customer Service
New Systems

Hart III, John: Quality Assurance Emphasized at Western Union.
Western Union TECHNICAL REVIEW, Vol. 23, No. 1 (Jan. 1969)
pp. 4-13.

An expanded Quality Assurance program has been installed at Western Union, which will assure its customers ever increasing reliability in Western Union Systems and Services.

Quality Assurance comprises Performance Control, Reliability Control, Quality Control and Configuration Control. These four areas are defined and functional block diagrams are included.

System Performance
Communication Systems
Quality Assurance

Svarczkopf, G. J.: System Performance in Communication Systems
Western Union TECHNICAL REVIEW, Vol. 23, No. 1 (Jan. 1969)
pp. 14-19.

The primary goal of a communication system is 100 percent satisfactory performance for the customer. Western Union continuously alters its existing plant so that many different services can be integrated into a single system.

This article deals with some of the factors that must be considered in achieving a system performance which is 100% satisfactory. From a study of all factors, some measurable parameters may be ascertained which reflect the "quality" of a system.

Configuration Control
Configuration Management
Quality Assurance
Equipment Changes

Carpenter, D. J.: Configuration Management in Western Union.
Western Union TECHNICAL REVIEW, Vol. 23, No. 1 (Jan. 1969)
pg. 20-25.

This article describes one way Western Union effects control over the configuration of its systems.

For many years problems of equipment change were easily resolved. Most field and internal equipments could be readily modified because they were simple and relatively unsophisticated. Because of the pressures for rapid change and management's need to know the status of change immediately, many electronics companies now use a system known as Configuration Control or Configuration Management as an answer to this need. Knowledge of reasons-for-change, how the function of the equipment is affected by a change, provides management with effective evaluation of performance. It is for these basic reasons that the Configuration Management program has been set up at Western Union.

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Management Tool
Quality Assurance
Review Boards
Corrective Action

Montemurno, M. V.: Management Reviews—Help Keep Pace with Western Union's Expanded Services.

Western Union TECHNICAL REVIEW, Vol. 23, No. 1 1969
pp. 26-31.

A general look at the management tool, Review Boards, is made in this article, leading to the formation of Western Union's Corrective Action Committee. Because of the complexity of new systems, Western Union has placed added emphasis on Quality Assurance, and has instituted the Quality Review Program which integrates management reviews.

This article describes some new management tools introduced into Western Union to keep pace with its growth and the expansion of its services.

Reliability
Quality Assurance
Service Requirements

Fink, Fred M.: Reliability Projection and Analysis
Western Union TECHNICAL REVIEW, Vol. 23, No. 1 (Jan. 1969)
pp. 32-40.

Service requirements for present Western Union Communication systems stress high standards of accuracy and operational continuity over long time intervals. Future service requirements will be even more stringent. The fulfillment of these performance requirements in an economical manner, is facilitated through an increased emphasis on the aspects of design, installation and utilization which yield a high system reliability.

For maximum effectiveness, reliability concepts must be continuously emphasized and applied throughout the design, development, and operational-maintenance periods of a system's lifetime. The individuals involved in the various stages of system development and operation are therefore required to be knowledgeable in the particular concepts and techniques of reliability engineering and analysis.

The purpose of this article is to illustrate and explain those basic concepts of reliability that are directly involved in the reliability activities.

Quality Assurance
Management
Awards

Hodgers, Jr., R. W.: Goals and Togetherness
Western Union TECHNICAL REVIEW, Vol. 23, No. 1 (Jan. 1969)
pp. 44

In this message from the Vice President of the Planning and Engineering Operation, Mr. R. W. Hodges, Jr., congratulates the authors of the January 1969 issue of the Western Union TECHNICAL REVIEW for having achieved and written a Quality Assurance manual.

He compares this fête to that of Apollo 8.

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Mary C. Killilea
Editor

Our Vice President's Message: January 17, 1969

Goals and Togetherness . . .

This issue of the TECHNICAL REVIEW, devoted to quality assurance, stresses more than ever, the importance of people—the importance of people dedicated to excellence at Western Union.

Just as the crew of Appollo 8, in its successful flight around the Moon, was dependent upon a large number of people—so Western Union's Management is dependent upon a large number of people—if they are to be successful in their job and in the goals they have set for Western Union.

If each person does his work and performs his job, so that what he does impacts someone else—together we can achieve "our goals."

Excellence depends on facilities and the operation of these facilities. Customer service depends on people. Quality assurance takes the best knowledge of our facilities, our operation—and defines for the customer the quality of service we offer him—our goal.

When President Johnson awarded the Distinguished Service Medals of NASA to the first circumnavigators of the Moon, he hailed them as "historys' boldest explorers." The citation praised them for "significantly advancing the nations capabilities in space."

Western Union's Management salutes the authors of this issue of the TECHNICAL REVIEW for "significantly advancing the company's quality assurance capability in communications."

This is but One Company. We shall move Forward Together.

R. W. Hodgers, Jr.

Vice President, P.&E.O.